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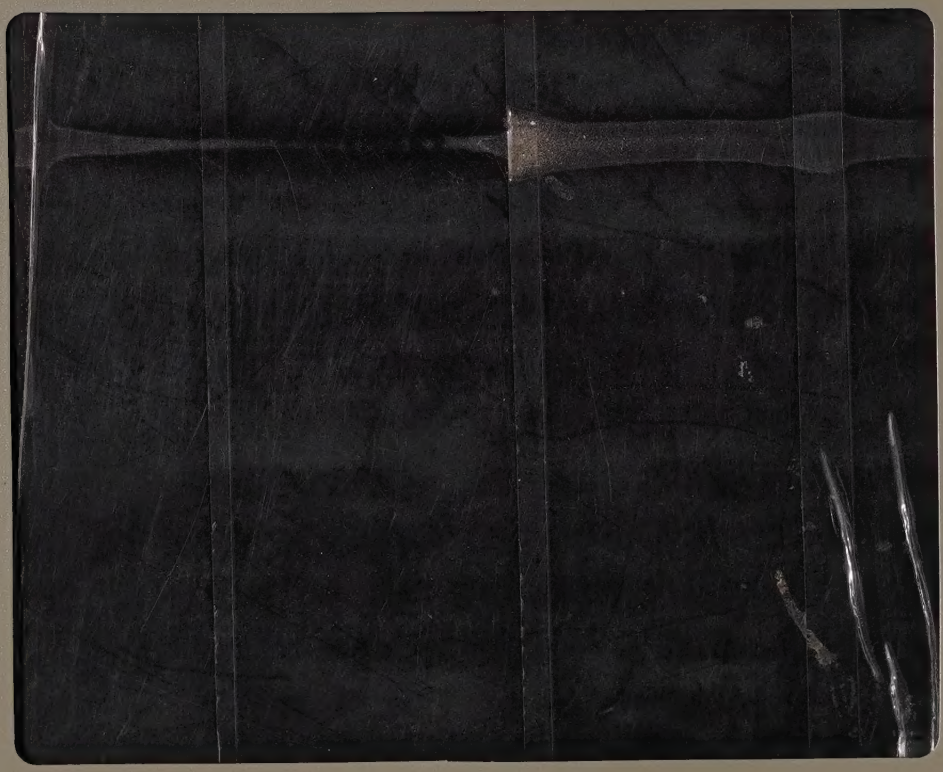
# 2165A
# Digital Thermometer

Instruction Manual

FLUKE®



File: F23

# 2165A
# Digital Thermometer

## Instruction Manual

P/N 445437
April 1976
Rev. 1 1/77

FLUKE®

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# WARRANTY

Notwithstanding any provision of any agreement the following warranty is exclusive:

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2. On receipt of the shipping instructions, forward the instrument, transportation prepaid. Repairs will be made at the Service Facility and the instrument returned, transportation prepaid.

**SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT**

All shipments of JOHN FLUKE MFG. CO., INC., instruments should be made via United Parcel Service or "Best Way"* prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

**CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER**

The instrument should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact the nearest Fluke Technical Center.) Final claim and negotiations with the carrier must be completed by the customer.

The JOHN FLUKE MFG. CO., INC, will be happy to answer all applications or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: JOHN FLUKE MFG. CO., INC., P.O. BOX C9090, EVERETT, WASHINGTON 98206, ATTN: Sales Dept. For European Customers: Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands.

*For European customers, Air Freight prepaid.

**John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, Washington 98206**

Rev. 6/81

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Section 1

# Introduction & Specifications

## 1-1. INTRODUCTION

1-2. The Model 2165A Digital Thermometer is a portable, four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of −200 to +2328°C or −328 to +3999°F. It features push-button selection of °C or °F, a four digit LED display, reference junction compensation (to eliminate the need for an ice bath reference junction), the choice of using any one-of-eight thermocouple types (J, K, E, T, R, S, B or C) as the input device, dual-slope measurement techniques and digital linearization of the thermocouple inputs. Several options and accessories are also available for use with the 2165A.

1-3. Push button controls include a power switch (ON/OFF), a temperature scale switch (°C/°F) and a charge switch (ON/OFF). When the unit is equipped with Ni-Cad batteries and is connected to line power, the charge switch (OFF) selects a trickle charge rate and simultaneous use of the instrument, or (ON) selects a fast charge rate but deactivates the instrument.

1-4. The front-panel display consists of five, seven-segment high-intensity LED's, and features leading-zero suppression. Four of the LED's are used to display numeric data, including a minus sign for negative temperature indications. The fifth LED displays the selected °C or °F scale character. An open-thermocouple detector causes the display to blink when an open circuit is sensed at the thermocouple input terminals.

1-5. Rear-panel, screw-type input connectors are provided for attaching the selected thermocouple. These terminals are an integral part of an isothermal block and serve as the reference junction for the reference-junction compensator. (The reference-junction compensator provides the physical and electrical equivalent of, and eliminates the need for, an ice bath reference junction at 0°C or 32°F.)

1-6. The actual measurement range of the 2165A is determined by the type of thermocouple being used as the input device. Any one of eight thermocouple types can be used; J, K, E, T, R, S, B or C. To ensure the proper linearization of the selected thermocouple input, a corresponding linearization program must be selected on the interior of the unit. Selection is accomplished by installing a type select pcb which corresponds to the input thermocouple. A single type select pcb is supplied with the unit to match the thermocouple type specified at the time of purchase. The remaining pcb's are individually available as accessories and are described in Table 1-1.

Table 1-1. 2165A ACCESSORIES

| MODEL NO. | DESCRIPTION |
|---|---|
| C80 | Carrying Case |
| C86 | Carrying Case |
| P20J | J-Type Thermocouple Probe |
| P20K | K-Type Thermocouple Probe |
| P20T | T-Type Thermocouple Probe |
| M00-100-714 | Front Panel Dust Cover |
| M00-200-611 | Rack Mounting Kit, Offset |
| M00-200-612 | Rack Mounting Kit, Center |
| M00-200-613 | Rack Mounting Kit, Side-by-Side |
| 2160A-7016 | J-Type Select PCB |
| 2160A-7017 | K-Type Select PCB |
| 2160A-7019 | E-Type Select PCB |
| 2160A-7018 | T-Type Select PCB |
| 2160A-7012 | R-Type Select PCB |
| 2160A-7013 | S-Type Select PCB |
| 2160A-7014 | B-Type Select PCB |
| 2160A-7015 | C-Type Select PCB |
| 2160A-7022 | Interface Cable |

1-7. Accessories and Options available for use with the 2165A are listed and described in Table 1-1 and 1-2, respectively. Detailed information concerning each option and accessory is given in Section 6 of this manual, Option and Accessory Information.

Table 1-2. 2165A OPTIONS

| OPTION NO. | DESCRIPTION | COMPATIBILITY | | |
|---|---|---|---|---|
| | | –01 | –02 | –04 |
| –01 | Rechargeable Batteries | – | YES | YES |
| –02 | Digital Output Unit | YES | – | NO |
| –04 | Analog Output Unit | YES | NO | – |

1-8. The 2165A is available in any one of three line power configurations: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Specify the required configuraiton at the time of purchase.

## 1-9. SPECIFICATIONS

1-10. Specifications for the 2165A are given in Table 1-3.

Table 1-3. SPECIFICATIONS

### ELECTRICAL

| | |
|---|---|
| **Compatible Thermocouple Types** | Unit can be calibrated to operate with any one of the following thermocouple types: J, K, T, E, R, S, B or C |
| **Measurement Method** | Dual-slope integration over a 100 ms period |
| **Zero Drift** | None. Automatic zero correction |
| **Reading Rate** | 2.5 readings per second |
| **°C to °F Conversion** | Switch selectable |
| **Input Characteristics** | |
| Input Connections | Screw terminals on isothermal connector |
| Input Circuit | Two-wire, isolated |
| Input Impedance | $> 100\ M\Omega$ |
| Input Current | $< 500$ pA |
| Source Impedance | $\leqslant 5k\Omega$. $5k\Omega$ causes $< 0.2°C$ (.36°F) error with k thermocouple |
| Overload | Display flashes when input voltage exceeds full-scale temperature range |
| Open Input | Display flashes to indicate open at input terminals |
| Maximum Input Voltage (without damage) | 400V dc or ac peak continuously between inputs or between either input and ground |
| Maximum Common Mode Voltage (without damage) | 400V dc or ac peak |
| Common Mode Rejection | $\geqslant 120$ dB @ 50, 60, 400 Hz $\pm 0.1\%$ with $1k\Omega$ source impedance unbalance |
| Normal Mode Rejection | $\geqslant 60$ dB @ 50, 60, 400 Hz $\pm 0.1\%$ |
| **Accuracy** | See Table 1 for °C specifications and Table 2 for °F specifications |
| **Response Time to Rated Accuracy** | $< 2.0$ seconds |
| **Linearization** | Digital with eight selectable programs in LSI ROM |
| **Linearization Programs** | |
| J, K, T and E | 32 straight line segments for positive inputs and 16 for negative inputs |
| R, S, B and C | 48 straight line segments for positive inputs |

Table 1-3. SPECIFICATIONS (Cont.)

**Reference Junction Compensation**

20 to 30°C (68° to 86°F)

| | |
|---|---|
| J, K, T, E | 0.025 degrees per degree |
| R, S | 0.05 degrees per degree |
| C | 0.02 degrees per degree |

0 to 20°C, 30 to 50°C (32 to 68°F, 86 to 122°F)

| | |
|---|---|
| J, K | 0.032 degrees per degree |
| T, E | 0.045 degrees per degree |
| R, S | 0.07 degrees per degree |
| C | 0.04 degrees per degree |

**Temperature Coefficient** . . . . . 0.005% of reading per °C

**Internal Temperature Rise** . . . . . ≤8°C (14.4°F)

Table 1. ACCURACY SPECIFICATIONS °C

| THERMOCOUPLE TYPE | TEMPERATURE RANGE °C | RESOLUTION AND REPEATABILITY (±C) | APPLICABLE TEMPERATURE RANGE °C | MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°C)* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | CALIBRATION ACCURACY | 20 min. to 24 hrs. 23 to 27°C | 90 Days 20 to 30°C | 1 Year 15 to 35°C | NBS CONFORMITY (±°C) |
| J | −200 to 778 | 1 | −200 to 0 | 1 | 1 | 1.5 | 1.5 | .19 |
| | | | 0 to 778 | 1 | 1 | 1 | 1.5 | .15 |
| K | −200 to 1356 | 1 | −200 to 0 | 1 | 1 | 1.5 | 2 | .20 |
| | | | 0 to 1356 | 1 | 1 | 1.5 | 2 | .18 |
| T | −200 to 400 | 1 | −200 to 0 | 1 | 1 | 1.5 | 2 | .19 |
| | | | 0 to 400 | 1 | 1 | 1 | 1 | .15 |
| E | −200 to 1000 | 1 | −200 to 0 | 1 | 1 | 1.5 | 2 | .17 |
| | | | 0 to 1000 | 1 | 1 | 1 | 1.5 | .18 |
| R | 0 to 1778 | 1 | 0 to 1778 | 1.5 | 1.5 | 2.5 | 3 | .26 |
| S | 0 to 1778 | 1 | 0 to 1778 | 1.5 | 1.5 | 2 | 3 | .22 |
| B | 533 to 1844 | 1 | 533 to 1844 | 1.5 | 1.5 | 2 | 2.5 | .29 |
| C | 0 to 2328 | 1 | 0 to 2328 | 2 | 2 | 3 | 3 | .36 |

* Includes reference junction and conformity errors. Excludes thermocouple errors.

Table 1-3. SPECIFICATIONS (Cont.)

Table 2. ACCURACY SPECIFICATIONS °F

| THERMOCOUPLE TYPE | TEMPERATURE RANGE °F | RESOLUTION AND REPEATABILITY (± °F) | APPLICABLE TEMPERATURE RANGE °F | MAXIMUM ERROR INCLUDING NBS CONFORMITY (± °F)* | | | | NBS CONFORMITY (± °F) |
|---|---|---|---|---|---|---|---|---|
| | | | | CALIBRATION ACCURACY | 20 min. to 24 hrs. 72 to 82 °F | 90 Days 68 to 86 °F | 1 Year 59 to 95 °F | |
| J | –328 to 1432 | 1 | –328 to 32<br>32 to 1432 | 1.5<br>1 | 1.5<br>1 | 2<br>1.5 | 2.5<br>2 | 0.27<br>0.2 |
| K | –328 to 2472 | 1 | –328 to 32<br>32 to 2472 | 2<br>1.5 | 2<br>1.5 | 2.5<br>2.5 | 3<br>3 | 0.28<br>0.26 |
| T | –328 to 752 | 1 | –328 to 32<br>32 to 752 | 1.5<br>1 | 1.5<br>1 | 2<br>1.5 | 3.5<br>2 | 0.3<br>0.2 |
| E | –328 to 1832 | 1 | –328 to 32<br>32 to 1832 | 1.5<br>1 | 1.5<br>1.5 | 2<br>2 | 3.5<br>2.5 | 0.25<br>0.25 |
| R | 32 to 3232 | 1 | 32 to 3232 | 2 | 2.5 | 4 | 5 | 0.4 |
| S | 32 to 3232 | 1 | 32 to 3232 | 2 | 2.5 | 3.5 | 4.5 | 0.33 |
| B | 992 to 3352 | 1 | 992 to 3352 | 2 | 2.5 | 3.5 | 4.5 | 0.45 |
| C | 32 to 3999 | 1 | 32 to 3999 | 3 | 3 | 5 | 5.5 | .58 |

*Includes reference junction and conformity errors. Excludes thermocouple errors.

## GENERAL

**Type of Display** . . . . . LED, 0.56 in high.

**Power Requirements**

Line Operation . . . . . 115V ac ±10%, 50 to 440 Hz, 8W. 100V ac and 230V ac versions are also available.

Battery Operation . . . . . 4.8V dc @ 350 mA (Four internal, D-size, Ni-Cad batteries, –01 option). Eight hours of operation on a full charge.

**Size** . . . . . 2.52 in (H) x 8.55 in (W) x 9.9 in (D) (6,40 cm x 21,72 cm x 25,25 cm). See Figure 1-1.

**Weight**

Without Batteries . . . . . 2 lbs. 10 oz. (1.19 kg)

With Batteries . . . . . 3 lbs. 15 oz. (1.79 kg)

## ENVIRONMENTAL

**Operating** . . . . . 0 to 50°C (32 to +122°F)

**Storage**

With Batteries . . . . . –40 to 60°C (–40 to 140°F)

Without Batteries . . . . . –40 to 75°C (–40 to 167°F)

**Humidity**

0 to 50°C (32 to 122°F) . . . . . 80% non-condensing

0 to 35°C (32 to 95°F) . . . . . 90% non-condensing

**Shock and Vibration** . . . . . Meets requirements of MIL Standard 810

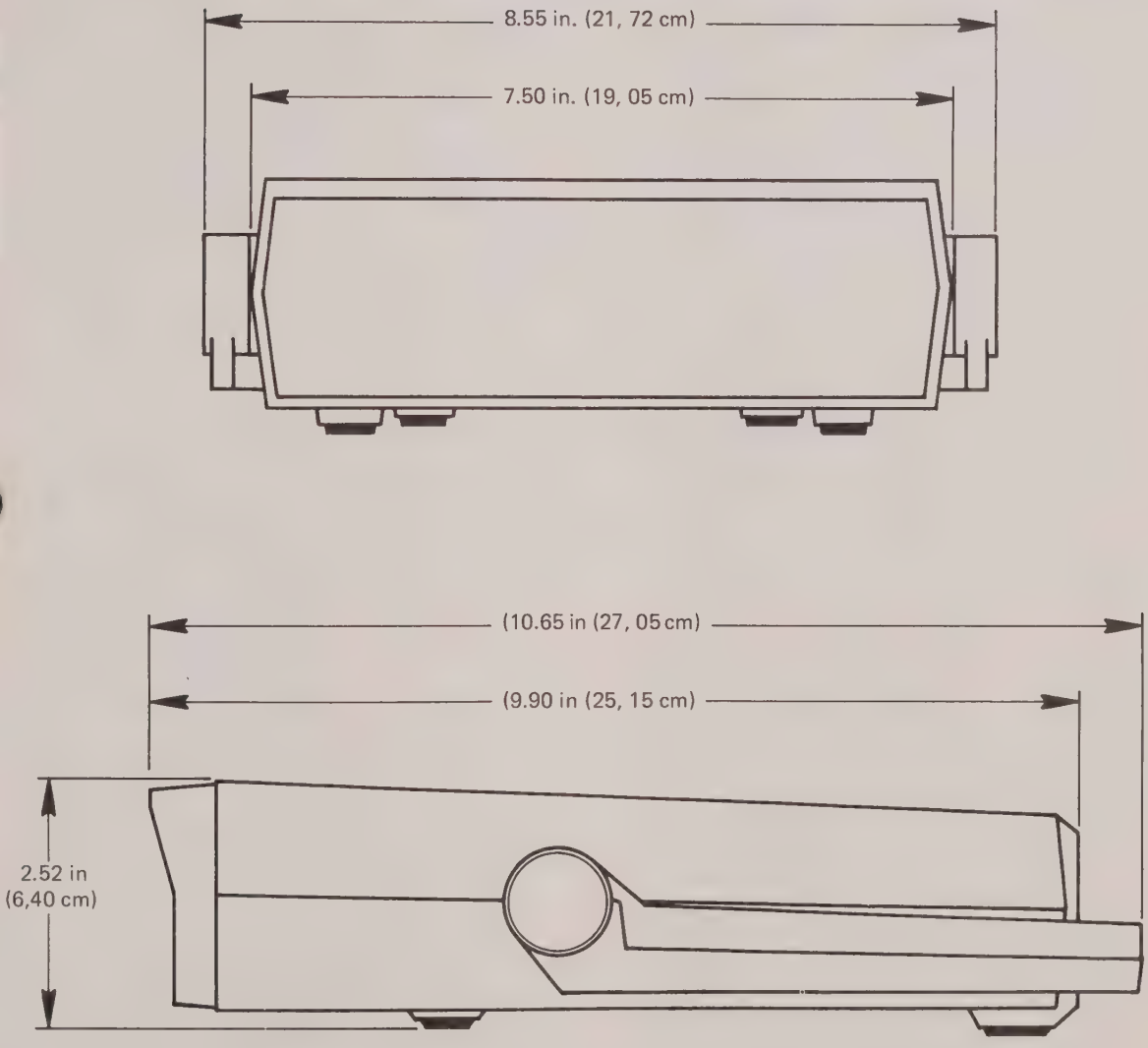
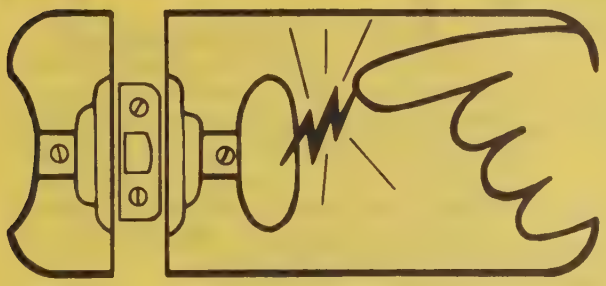



Figure 1-1. OUTLINE DRAWING

# static awareness

A Message From

**John Fluke Mfg. Co., Inc.**



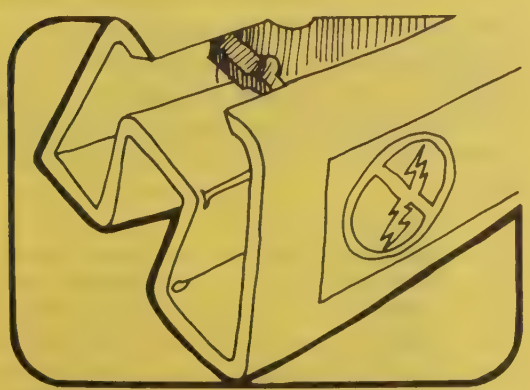
Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

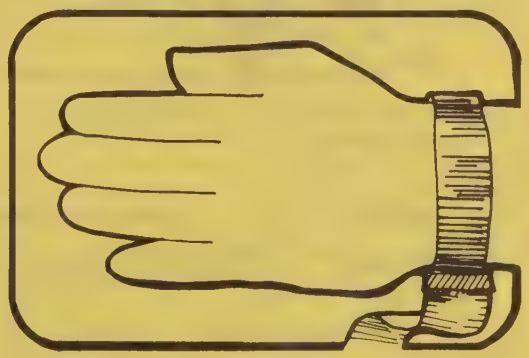
The Static Sensitive (S.S.) devices are identified in the Fluke technical manual parts list with the symbol "⊗"

The following practices should be followed to minimize damage to S.S. devices.

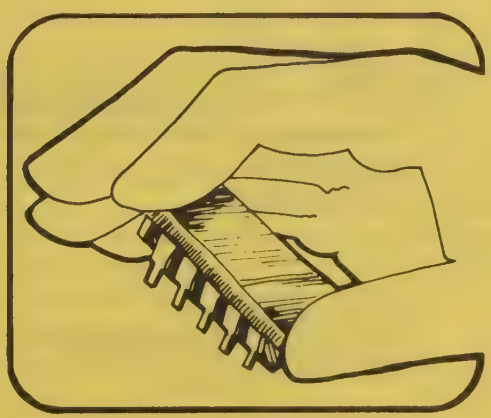
1. MINIMIZE HANDLING



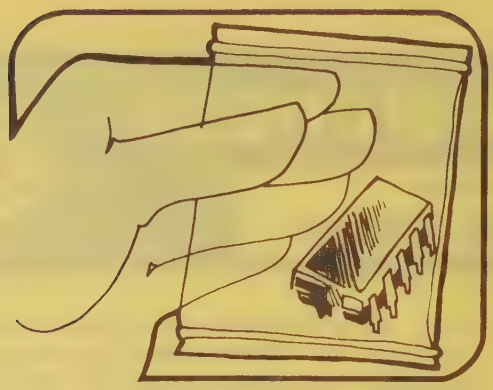
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



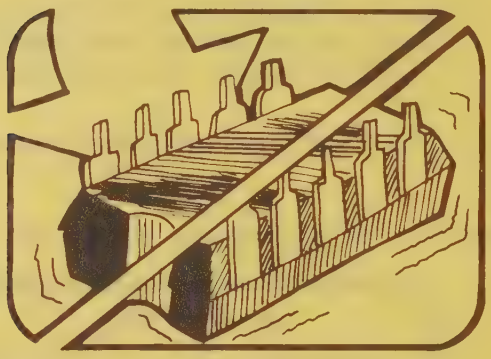
3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES



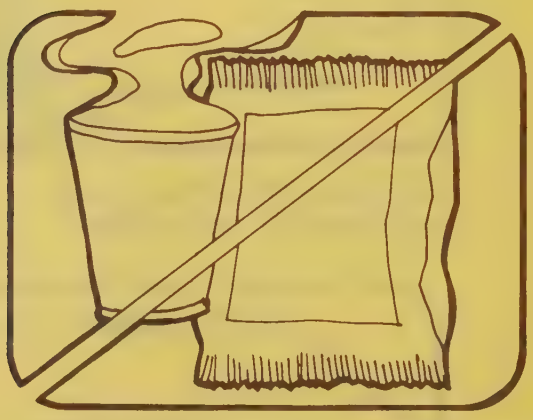
4. HANDLE S.S. DEVICES BY THE BODY



5. USE ANTI-STATIC CONTAINERS FOR HANDLING AND TRANSPORT



6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL AND STYROFOAM® IN WORK AREA

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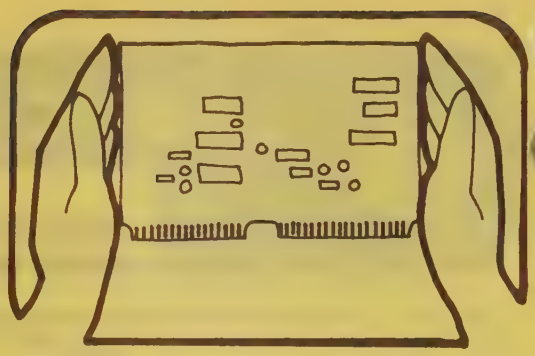
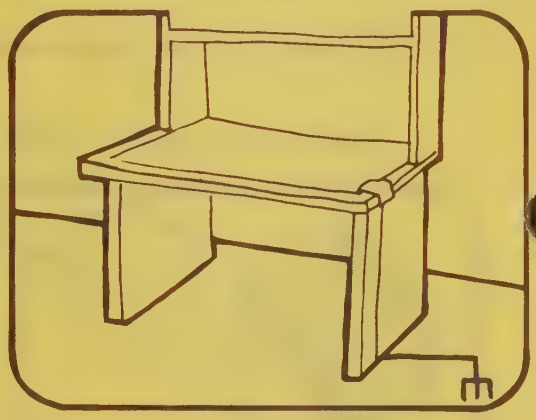
AND GENERAL DYNAMICS, POMONA DIV.

® Dow Chemical



8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR USUALLY PROVIDES COMPLETE PROTECTION TO INSTALLED SS DEVICES.



9. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION
10. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.
11. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

---

Anti-static bags, for storing S.S. devices or pcbs with these devices on them, can be ordered from the John Fluke Mfg. Co., Inc.. See section 5 in any Fluke technical manual for ordering instructions. Use the following part numbers when ordering these special bags.

| John Fluke Part No. | Description |
|---|---|
| 453522 | 6" X 8" Bag |
| 453530 | 8" X 12" Bag |
| 453548 | 16" X 24" Bag |
| 454025 | 12" X 15" Bag |
| Pink Poly Sheet 30"x60"x60 Mil P/N RC-AS-1200 $20.00 | Wrist Strap P/N TL6-60 $7.00 |



J0089B-07U7810/SE EN Litho in U.S.A.

# Section 2
# Operating Instructions

WARNING!

**Due to the possible presence of lethal voltages, the procedures in paragraphs 2-17 and 2-21 should be performed by qualified personnel only.**

## 2-1. INTRODUCTION

2-2. This section of the manual contains information regarding installation and operation of the Model 2165A Digital Thermometer. It is recommended that the contents of this section be read and understood before any attempt is made to operate the instrument. Should any difficulties arise during operation, please contact your nearest Fluke Technical Service Center, or the John Fluke Mfg. Co., Inc., P.O. Box 43210, Mountlake Terrace, WA 98043, Tel. (206) 774-2211. A list of Technical Service Centers is located in Section 7 of this manual.

## 2-3. SHIPPING INFORMATION

2-4. The 2165A is packaged and shipped in a foam-packed container. Upon receipt of the instrument, a thorough inspection should be made to reveal any possible shipping damage. Special instructions for inspection and claims are included in the shipping carton.

2-5. If reshipment of the instrument is necessary, the original container should be used. If the original container is not available, a new one can be obtained from the John Fluke Mfg. Co., Inc. Please reference the instrument model number when requesting a new shipping container.

## 2-6. INPUT POWER

2-7. The 2165A is factory wired to operate from one of three ac line voltages. These are: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Before connecting the 2165A to the ac line, check to ensure that the instrument is wired to accommodate the local line voltage. A decal on the underside of the unit defines the particular line voltage required to operate the instrument.

2-8. The rear panel ac input connector is a three-prong, U-ground connector which permits the instrument to be connected, via the power cord, to the appropriate line voltage. The offset prong on this connector is connected to the 2165A power supply, and should be connected through the power cord to a high quality earth ground.

## 2-9. RACK INSTALLATION

2-10. The 2165A is designed for field and bench-top use or for installation in a standard 19-inch equipment rack using an accessory rack-mounting kit. Kits are available for left, right, center or side-by-side mounting of the 2165A. Information about rack mounting accessories is given in Section 6 of this manual, Option and Accessory Information.

## 2-11. OPERATING FEATURES

2-12. The location of all 2165A controls, indicators and connectors are shown in Figure 2-1, and described in Table 2-1.

## 2-13. OPERATING NOTES

2-14. The following paragraphs describe various conditions which should be considered before operating the 2165A.

### 2-15. Option Information

2-16. Supplementary operating instructions are necessary when operating a 2165A which is equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information.

### 2-17. Fuse Replacement

WARNING!

**Disconnect the unit from line power before attempting to replace the fuse.**

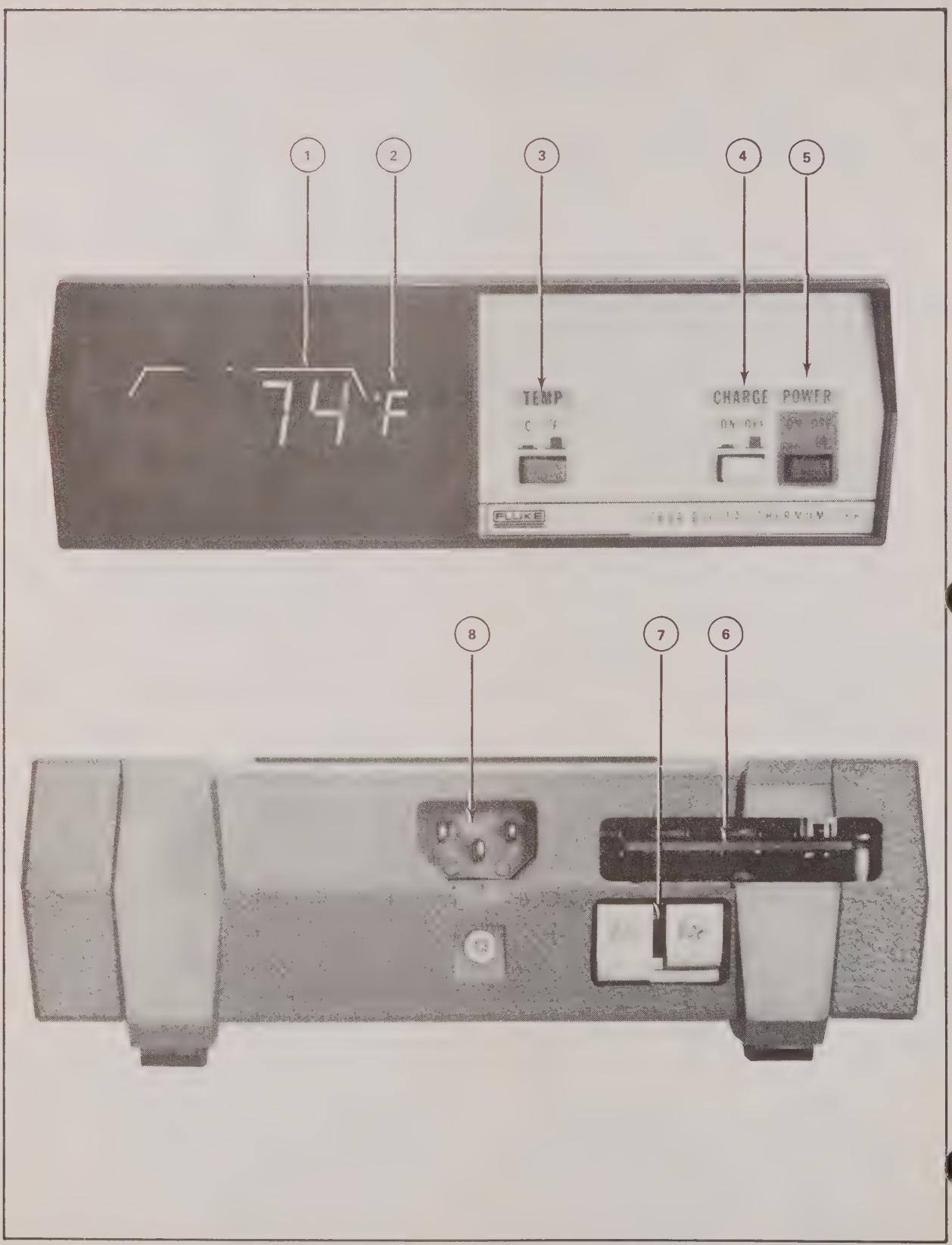



Figure 2-1. CONTROLS, INDICATORS & CONNECTORS

Table 2-1. 2165A CONTROLS, INDICATORS AND CONNECTORS

| REF. NO. | NAME | FUNCTION |
|---|---|---|
| 1 | Digital Display | Displays a four digit readout of the measured input temperature. Leading-zero suppression is also included. A minus sign is displayed for negative temperature measurements. The absence of a polarity sign indicates a positive temperature measurement. |
| 2 | Temperature Scale Indicator | Displays the temperature scale represented by the digital display data; °C or °F. |
| 3 | TEMP Select Switch | Selects the temperature scale for the digital display. When the switch is depressed (IN), the °C scale is selected. The °F scale is selected when the switch is released (OUT). |
| 4 | CHARGE Switch | Selects the charge rate when the Battery Option (–01) is installed. When the switch is depressed (IN) the fast charge rate is enabled and the thermometer is not operational. The unit is operational when the CHARGE switch is released (OUT), and the batteries are charged at a trickle rate. |
| 5 | POWER Switch | Switches the 2165A on or off. The unit is turned on when the switch is depressed. |
| 6 | DOU, AOU I/O Port | Provides access to the input/output connector of the Digital Output Unit (Option –02) or the Analog Output Unit (Option –04) when either option is installed. |
| 7 | Thermocouple Input Connections | Provides screw-type input terminals for connecting the thermocouple to the thermometer. |
| 8 | Input Power Connector | Provides the means of connecting the instrument through the power cord to ac line power. |

2-18. The ac line-input section of the 2165A power supply is fuse protected. The fuse is located on the interior of the unit near the power transformer. To access the fuse, remove the rear-panel retaining screw located beneath the ac line connector, and pull the case from the instrument. When replacement is necessary, use a MDL (Slo-blo) 1/8A fuse.

## 2-19. Overload and Open Thermocouple Indication

2-20. The front panel display, in addition to providing a measurement reading, is designed to serve as an overrange or open thermocouple indicator. When the measurement range of the input thermocouple is exceeded, or when the thermocouple inputs are open circuited, the display will blink. The blinking indications does not mean that the instrument is being exposed to a damaging input condition.

## 2-21. Thermocouple Compatibility

2-22. The 2165A is designed to operate in conjunction with a selected type of thermocouple probe. A decal on the bottom of the unit identifies the compatible thermocouple type. When necessary, the 2165A can be modified in the field to accommodate any one of the following thermocouple types: J, K, E, T, R, S, B or C. Use the following procedure to change thermocouple types:

a. Refer to Table 1-1 in Section 1 of this manual and order the linearizer pcb which corresponds to the desired thermocouple type. These pcbs are low-cost items and can be purchased from any one of the John Fluke Technical Service Centers (See Section 7) or from the John Fluke Mfg. Co., Inc.

b. Disconnect the 2165A from line power.

c. Remove any ribbon-cable connectors that may be attached to the rear of the 2165A.

d. Disconnect the power cord from the rear of the unit.

e. Remove the rear-panel screw located just below the power input connector.

f. Pull the 2165A front panel and pcb assembly out the front of the plastic case.

g. Unplug and remove the currently installed type select pcb from the position shown in Figure 2-2, and install the new one in its place.

*NOTE*

*The thermocouple type is etched on the type select pcbs. When properly installed the arrows on the linearizer pcb point toward the digital display.*

h. Place a piece of tape over the thermocouple type indications on the bottom-side decal, and mark the new thermocouple type on it.

i. Connect the new thermocouple type probe to the thermocouple input terminals. Observe polarity shown on bottom-side decal.

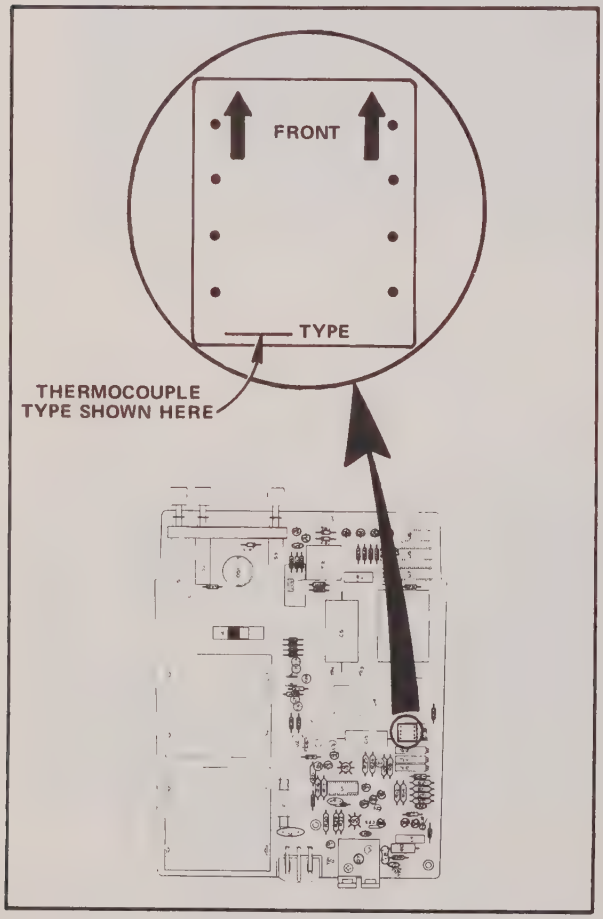



Figure 2-2. TYPE SELECT PCB, LOCATION AND INSTALLATION DETAILS

j. Connect the unit to line power, and complete the routine calibration procedure given in Section 4 (Maintenance) of this manual.

k. Install the unit in its case.

## 2-23. CHARGE Switch

2-24. The front panel CHARGE switch is operational only when the 2164A is equipped with the Battery Option (–01) and LINE/BATT switch on the interior of the unit set to (BATT). (If the switch is not set to BATT, installed batteries will not provide power nor receive a charge.) When the charge function is enabled (BATT) and the unit is operating from line power, depressing the CHARGE switch causes the batteries to be charged at a fast rate. The thermometer operation is disabled for the duration of the fast charge period. When the CHARGE switch is out, the thermometer is operational and the batteries are charged at a trickle rate.

## 2-25. OPERATION

2-26. With reference to previous paragraphs in this section, use the following procedure to operate the 2165A:

a. Refer to the bottom decal on the unit and connect a compatible thermocouple probe to the thermocouple input terminals. Observe polarity as shown on decal.

b. Connect the unit to the appropriate line power (not necessary if the unit is equipped with a charged set of batteries) as defined on the bottom decal.

c. Energize the unit by depressing the POWER switch.

d. Set the CHARGE switch to the OFF position. See Section 6 for details concerning battery operation (Option –01).

e. Set the TEMP switch to the desired temperature scale, °C or °F.

f. Refer to Section 6 of this manual for instructions concerning the operation of the –02 and –04 Options.

g. Expose the thermocouple probe to a temperature within its specified range (See bottom decal). The probe temperature will be displayed on the front panel.

# Section 3
# Theory of Operation

## 3-1. INTRODUCTION

3-2. This section of the manual contains an overall functional description followed by a circuit analysis of the 2165A. Simplified circuit diagrams and timing diagrams are included, as necessary, to supplement the text. Detailed schematics are given in Section 8 of this manual.

## 3-3. OVERALL FUNCTIONAL DESCRIPTION

3-4. The Model 2165A Digital Thermometer, as shown in Figure 3-1, is a four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of –200 to +2328°C or –328 to +3999°F. It features a reference junction compensator (to eliminate the need for an ice-bath reference junction), dual-slope integration, LSI digital control logic (includes linearization programs for J, K, E, T, R, S, B and C type thermocouples), and a four-digit LED display.

3-5. In operation, the 2165A executes a continuous series of measurement cycles to update the temperature display. The measurement cycle is controlled entirely by an LSI digital IC, and includes three major subcycles; Auto-Zero period, Integrate period and Read period. Each subcycle controls the operation of the analog section of a dual-slope integrator which, in turn, generates a compare output to control the digital conversion performed by the LSI digital IC.

3-6. The configuration of the analog section of the 2165A, during each phase of the measurement cycle, is established by a combination of FET switches that are controlled by the LSI digital IC. The measurement cycle begins with the Auto-Zero period. During this period, the reference junction compensation voltage and the accumulated dc offset voltages present in the analog section are sampled and held by capacitors. These voltages are used later in the measurement cycle to cancel measurement errors introduced by offset voltages and reference junction voltage errors created at the input terminal connections. As a result, the final measurement is

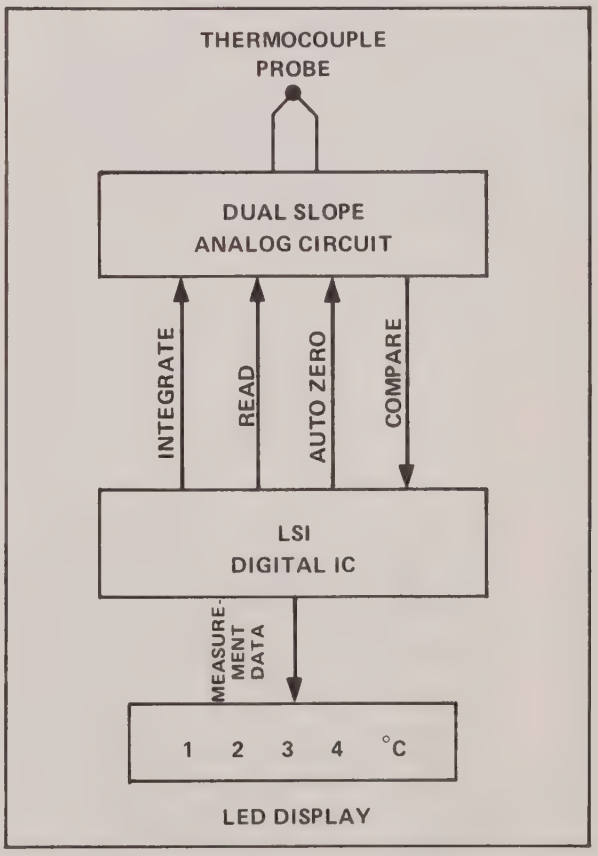



Figure 3-1. 2165A SIMPLIFIED BLOCK DIAGRAM

proportional to the thermocouple probe output voltage and does not include offset errors or reference junction voltage errors. During the Integrate period, the thermocouple input voltages (probe voltage and input terminal voltages) are applied to the integrator, and the algebraic sum of these voltages is integrated over a 100 ms period. At the end of this period, the thermocouple input voltages are removed from

the integrator and the Read period is started. A reference voltage is applied to the integrator during the Read period causing the integrator capacitor to be discharged at a linear rate. When the integrator output reaches zero, a compare signal is generated to end the Read period. The duration of the Read period is translated by the LSI digital IC to provide a digital indication proportional to the thermocouple probe temperature.

## 3-7. CIRCUIT ANALYSIS

3-8. Circuit analysis of the 2165A is discussed in two sections; digital and analog. The digital section is covered first, and particular attention is paid to the control it exercises on the analog section. The analysis of the analog section covers the analog measurement circuitry and the 2165A power supply.

### 3-9. Digital Section

3-10. The digital section of the 2165A consists of an LSI digital IC, a hex buffer, a seven-segment decoder/driver and an LED display. Its function is to convert the non-linear thermocouple probe voltage, as measured by the analog section, into a linear digital display. The display provides a direct reading of probe temperature in °C or °F.

3-11. The LSI digital IC contains all of the 2165A control logic and linearizing capability, and provides the hex buffer and seven-segment decoder with the data necessary to update the LED display. The linearization of the nonlinear input signal is accomplished by selecting one of eight programs which vary the rate at which the measurement counts are accumulated. The program is selected to match a particular thermocouple type. Program selection is accomplished by a series of plug-in type select pcb's which are available as accessories.

3-12. Measurement data is continuously strobed out of the LSI digital IC in bcd, character-serial format. At the end of each measurement cycle, an update flag is raised to signify that a new reading is available. When an overload occurs, the number of accumulated counts are stored and presented, along with a blanking pulse, as output data. The blanking pulse alternately turns the display on and off to indicate the presence of an overload.

3-13. The basic measurement cycle, as shown in Figure 3-2, comprises three subcycles; a 100 ms minimum Auto-Zero period, a 100 ms Integrate period, and a variable Read period. The auto-zero period is extended to 300 ms when an overload occurs. To accommodate settling times in the analog section, a 500 us hold signal is inserted at the beginning and at the end of the Integrate period.

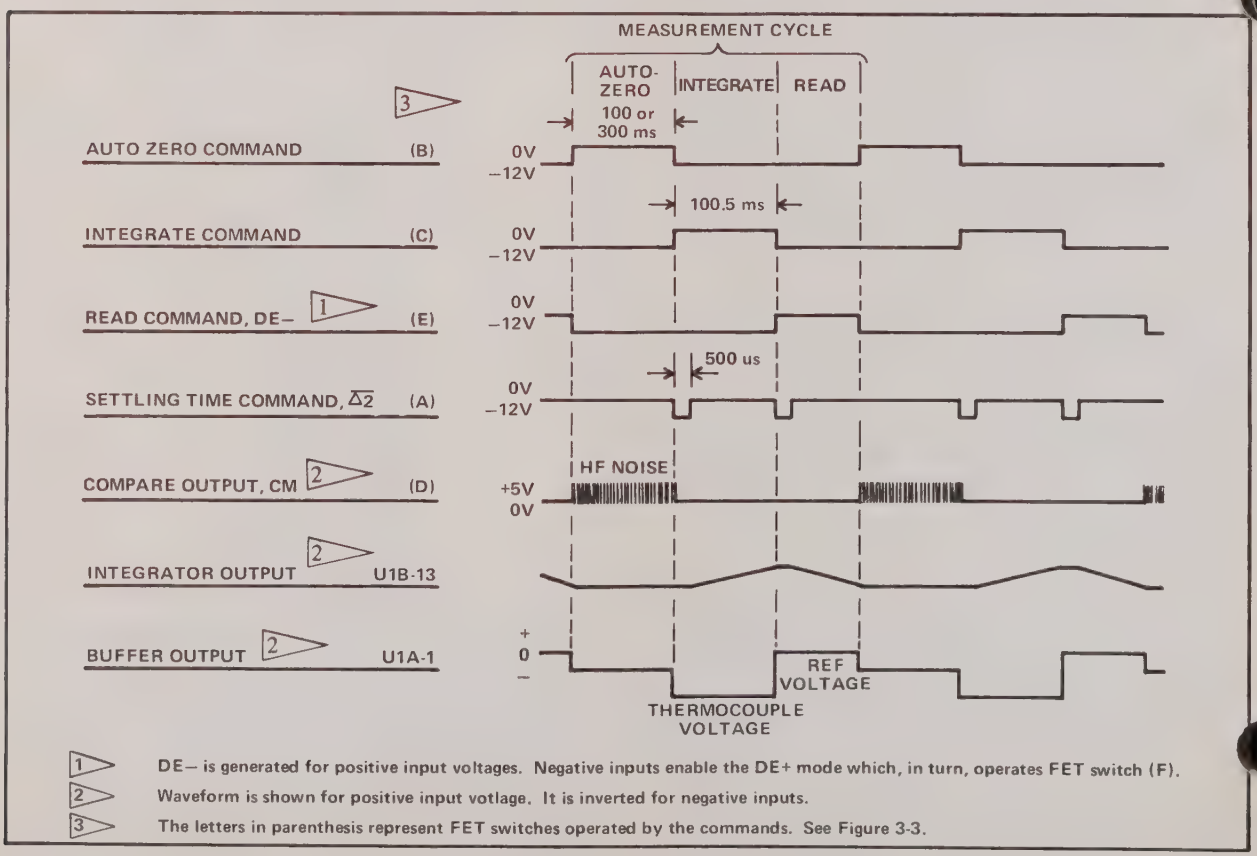



Figure 3-2. MEASUREMENT CYCLE WAVEFORMS

## 3-14. Analog Section

3-15. ANALOG MEASUREMENT CIRCUIT

3-16. The analog measurement circuit is shown in simplified form in Figure 3-3. It consists of a thermocouple input circuit, a reference-junction compensator, a voltage reference, a Buffer Amplifier, an Integrator, a Comparator, and a combination of FET switches. The switches are shown in their open state and are closed by the measurement cycle commands generated by the LSI digital IC. Each switch is assigned a letter designation which corresponds to a measurement cycle command shown in Figure 3-2.

3-17. The Thermocouple Input circuit consists of an R-C filter and a pair of voltage protection diodes. The difference between the thermocouple probe voltage and the input terminal voltage is passed through the filter and appears at the arm of switch C.

3-18. The Reference-Junction Compensator consists of an isothermal block, a pair of screw type input terminals, and a transistor temperature sensor. The isothermal block maintains a known temperature differential between the input terminals and the temperature sensing transistor. Thermocouple voltages introduced by the dissimilar metals at the input terminals vary as the isothermal block adjusts to ambient temperature. Temperature changes are sensed by the forward-biased transistor which produces a correction voltage equivalent to the thermocouple voltage created at the input terminals. Predictable characteristics of a forward-biased P-N junction allow the Reference-Junction Compensator to function over a wide temperature range. The correction voltage is matched to the thermocouple probe type by a selected Offset Resistor which is supplied on a plug-in type select pcb. The correction voltage appears at the arm of switch B1.

3-19. The voltage reference consists of a resistor divider which is supplied by an accurate 6.4V dc reference voltage. The divider is calibrated to match the thermocouple probe type by a selected resistor on the plug-in type select pcb. Two voltages are available at the divider outputs; 0.5 x V ref, and 1.5 x V ref. These voltages appear at the arms of switches B2 and E, respectively.

3-20. The Buffer, Integrator and Comparator amplifiers combine to perform the analog functions of the Integrate, Read and Auto-Zero periods. The Buffer is used to provide integrator inputs during all three periods. The Integrator integrates the Buffer output voltage during the Integrate and Read periods, and functions, in combination with the Comparator, as a closed-loop amplifier during the Auto-Zero period.

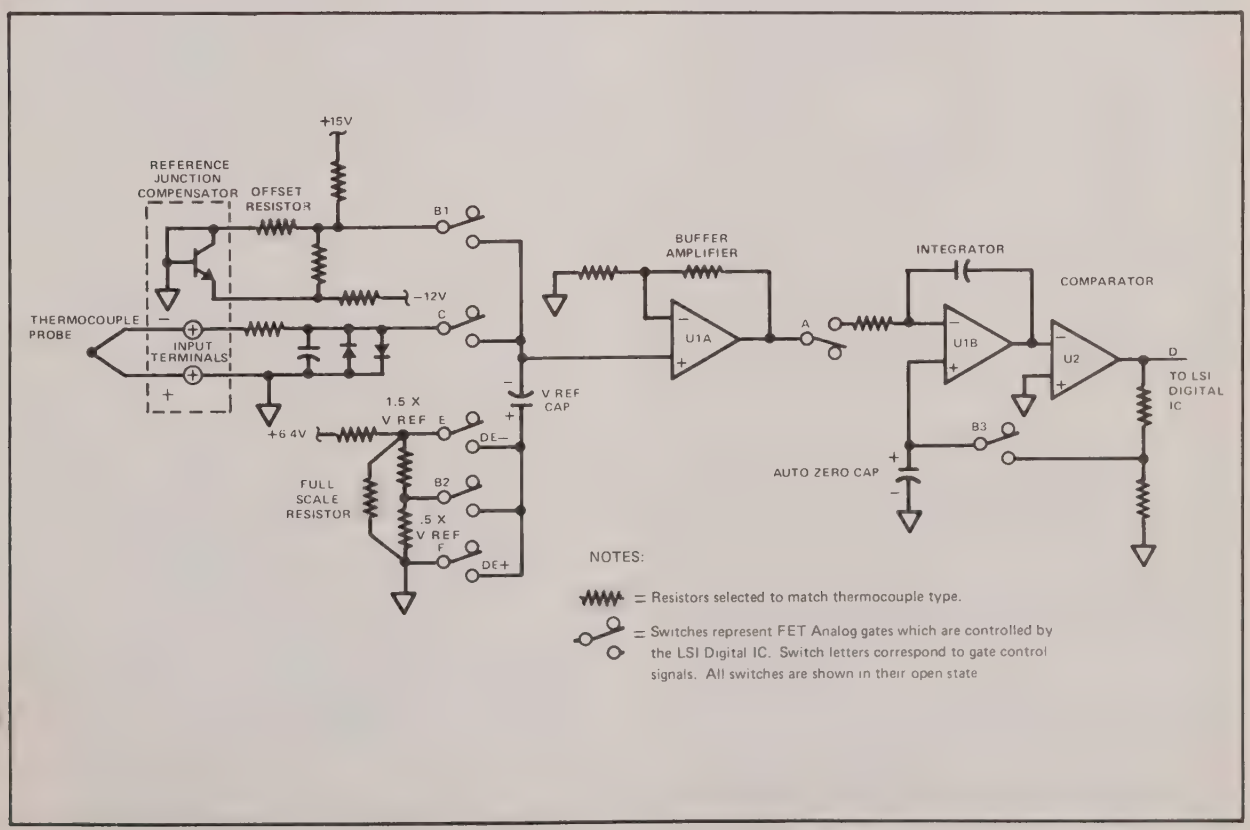



Figure 3-3. ANALOG SECTION, SIMPLIFIED CIRCUIT DIAGRAM

3-21. During the first phase of each measurement cycle, the analog section goes through an Auto-Zero period. During this time, three auto-zero switches (B1, B2 and B3) are closed by the Auto Zero command from the LSI digital IC. Two of the switches (B1 and B2) charge the V ref capacitor to a level equal to the algebraic sum of the 0.5 x V ref output, plus the correction voltage generated by the Reference-Junction Compensator. At the same time, the correction voltage is amplified by the Buffer Amplifier and presented through switch A to the Integrator input. The third switch (B3) connects the Integrator and Comparator in a closed loop configuration and allows the Auto-Zero capacitor to charge to a value which is proportional to the Reference-Junction-Compensator correction voltage plus the offset voltages present in the Buffer, Integrator and Comparator amplifiers. At the end of the measurement cycle switches B1, B2 and B3 are opened. The V ref capacitor and the Auto-Zero capacitor retain their charge for use later in the measurement cycle.

3-22. The Integrate period starts on the leading edge of the Integrate Command from the LSI digital IC; switch A is open and switch C is closed. The thermocouple input voltage is applied through switch C to the Buffer input. After a 500 us settling period, switch A closes and the Buffer output voltage is applied to the Integrator input for 100 ms. As the integrator capacitor charges, the Integrator drives the Comparator output to either 0 or +5V dc to indicate the polarity of the thermocouple input voltage, positive or negative, respectively. The comparator output is sent to the LSI digital IC for use during the Read period. At the end of the Integrate period, the integrator capacitor is charged to a level and polarity that is proportional to the thermocouple probe voltage and switch C returns to its open state.

3-23. The Read period starts at the end of the Integrate period and one-of-two Read Modes is enabled depending upon the input polarity sensed by the comparator during the Integrate period. If a positive input is sensed, a DE– Read Mode is enabled. Similarly a DE+ Read Mode is enabled when a negative input is sensed.

3-24. If the DE– Read Mode is commanded, switch A is opened and E is closed. Switch E applies a 1.5 x V ref input to the positive side of the V ref capacitor. This voltage is algebraicly added to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction-Compensator voltage). As a result, the input to the Buffer Amplifier is a positive voltage equal to V ref plus the Reference Junction-Compensator voltage.

3-25. If the DE+ Read Mode is commanded, switch A is opened and F is closed. Switch F grounds the positive side of the V ref capacitor and causes the Buffer amplifier input to be driven to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction Compensator voltage). As a result, the input to the Buffer Amplifier is a negative voltage equal to 0.5 x V ref plus the Reference-Junction-Compensator voltage.

3-26. After a 500 us settling time, switch A closes and the Buffer output voltage is applied to the Integrator input. This causes the integrator capacitor to discharge at a linear rate determined by the reference voltage. The discharge continues until the integrator output voltage reaches zero volts, the level existing prior to the integrate period. This level is sensed by the Comparator which signals the LSI digital IC to terminate the A/D conversion of measurement data.

3-27. Offset voltages present during the Integrate and Read periods are cancelled out by offset voltages that were sampled and held during the Auto-Zero period. However, the Reference-Junction-Compensator voltage (also sampled and held during Auto Zero) is added to the integrator voltage during the Integrate period. As a result, the displayed temperature is equal to the thermocouple probe temperature.

3-28. POWER SUPPLY

3-29. The 2165A power supply consists of a power transformer, fuse, power input connector, a dc-to-dc converter, battery holders, and associated regulating and charging circuits. The function of the power supply is to provide the unit with the necessary operating voltages during both battery and line operation, and to provide a means of recharging the Ni-Cad batteries, when installed. Operating voltages include: +5, +6.8, +15 and –12V dc, and 5V ac (rms). All voltages except the +5V dc and the 5V ac are regulated.

*NOTE*

*The 5V ac output is used to power the –02 and –04 options. Since this voltage is not generated during battery operation, the –02 and –04 options are operational only when the 2165A is operated from line power.*

3-30. The dc-to-dc converter is energized by a +5V dc input from the power transformer during line operation, or the rechargeable batteries during battery operation. Conventional regulating techniques produce +6.8, +15 and –12V dc operating voltages at the dc-to-dc converter output.

3-31. When batteries are installed in the 2165A and an internal Line/Battery switch is set to BATT, the front panel CHARGE switch is enabled. During line operation, the CHARGE switch provides selection of fast (ON) or slow (OFF) battery charge rates. The unit is operative only during slow-charge. However, during fast-charge the numeric display is blanked and the °C temperature scale character is lit. Lamp DSI operates as a ballast in the fast charge mode.

# Section 4
# Maintenance

**WARNING!**

**THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.**

## 4-1. INTRODUCTION

4-2. This section of the manual provides information about warranty, factory service, maintenance, performance testing, routine recalibration and recalibration after repair. The performance test is recommended when the instrument is received and later as a preventive maintenance tool or for testing after repair. The test verifies performance at several temperatures within the range of a given thermocouple type. Specifications are provided both for annual and for a more precise 90-day performance-testing cycle.

## 4-3. SERVICE INFORMATION

4-4. The instrument is warranted for a period of one year upon delivery to the original purchaser. The WARRANTY is located on the back of the title page located in the front of this manual.

4-5. Factory authorized calibration and service for each Fluke product is available at various world-wide locations. A complete list of these service centers is included in Section 7 of this manual. If requested, an estimate will be provided to the customer before any work is begun on instruments that are beyond the warranty period.

## 4-6. GENERAL MAINTENANCE

### 4-7. Access Information

4-8. Use the following procedure to gain access to the interior of the instrument:

a. Set the POWER switch to OFF and disconnect the ac power cord from the unit.

b. Disconnect the thermocouple probe at the input terminals.

c. Remove the phillips-head screw located in the center of the rear panel.

d. Pull the instrument out of the front of the case.

### 4-9. Cleaning

4-10. Clean the instrument periodically to remove dust, grease and other contamination. Use the following procedure:

**CAUTION!**

**Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They will react with plastic materials used in manufacture of the instrument.**

a. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.

b. Clean the surface of the pcb using clean dry air at low pressure ($\leq$ 20 psi). If grease is encountered, spray with Freon T. F. Degreaser or anhydrous alcohol and remove grime with clean dry air at low pressure.

## 4-11. Fuse Replacement

**WARNING!**

**DISCONNECT THE UNIT FROM LINE POWER BEFORE ATTEMPTING FUSE REPLACEMENT.**

4-12. The input power fuse is located on the interior of the unit near the ac line connector. If replacement is necessary, use an MDL (Slo-blo) 1/8A fuse.

## 4-13. Service Tools

4-14. No special tools are required for maintenance or repair.

## 4-15. PERFORMANCE TEST

4-16. Table 4-1 lists the equipment required for performance testing and recalibration. If the recommended model of test equipment is not available, a substitute that meets the minimum use specifications may be used. Table 4-2 outlines the Performance Test. A Performance Checklist at the end of this section may be reproduced or removed to provide a written record of results. The Performance Test verifies instrument performance to specifications for initial acceptance or for maintenance. (Periodic recalibration requires the calibration procedure beginning in paragraph 4-27). If the thermometer fails to meet specifications, it requires recalibration or repair. Review Table 4-2, then continue.

*NOTE*

*The Performance Test should be conducted at an ambient temperature of 25 ± 2° C (77 ± 3.6° F).*

Table 4-1. TEST EQUIPMENT REQUIREMENTS

| TEST EQUIPMENT | MINIMUM USE SPECIFICATIONS | RECOMMENDED MODEL |
|---|---|---|
| Thermocouple Probes | Type J, K, T, E, R, S or C (select type compatible with thermometer) | Omega TJ36 Series, Grounded Sheath |
| Mercury, thermometer (either °C or °F) | 0.02°C Resolution<br>0.05°F Resolution | Princo Model ASTM-56C<br>Princo Model ASTM-56F |
| Dewar Flask/Cap | 1-pint capacity | Thermos |
| DC Voltage Calibrator | Output Voltage: 0 to 10V<br>Accuracy: 0.002%<br>Resolution: 10 mV | Fluke Model 343A |
| Voltage Divider 100:1 or Kelvin-Varley Divider (Shunt output with 1 uf capacitor) | Ratio: 0.005% | Fluke A21-5 or Fluke 720A or Fluke 750A |
| Variable Line-Voltage Transformer | 100, 115, 230V ac, as required, ±10% | General Radio VARIAC W5HM |
| Decade Resistor | Accuracy: 1%<br>Ranges: 1K, 10K and 100K | General Radio 1434 |

## 4-17. Set-up Procedure

4-18. The following steps prepare for performance testing:

a. Remove the thermometer from its case.

b. Check the position of the line-battery switch. An instrument with no batteries should have the switch set to LINE position. An instrument containing batteries should have the switch set to the BATT position.

Table 4-2. PERFORMANCE TEST DESCRIPTION

| TEST | PERFORMANCE SPECIFICATIONS | TEST METHOD | BEGINNING TEXT PARAGRAPH |
|---|---|---|---|
| Setup | | | 4-17 |
| Overload and Open Input Test | The display flashes to indicate both over range input voltages and open input terminals. | An over range voltage is applied to the thermocouple input terminals, and the input terminals are open circuited. | 4-19 |
| Line Voltage Regulation | Satisfactory performance with any line voltage within ±10% of nominal; 100, 115 or 230V ac | The display is monitored during the accuracy test as the line voltage is varied. | 4-21 |
| Accuracy Test | Temperature Accuracy as stated in Table 4-3 | Known input voltages are substituted for the thermocouple inputs. Cardinal-point checks ensure accuracy over the entire temperature range. | 4-23 |
| Internal Temperature Rise | < 8°C (14.4°F) above ambient | The thermocouple input terminals are shorted and the temperature of the reference junction is displayed. | 4-25 |

c. Locate the RJD switch on the main pcb (See Figure 4-1) and set it to the RJD position. (This defeats the reference-junction circuitry.)

d. Connect a voltage divider to a dc voltage calibrator as in Figure 4-2. (See Table 4-1 for specifications.)

e. Connect the voltage-divider output to the thermometer input terminals. Match polarity.

f. Connect a variable line-power transformer to line power and adjust the output to the nominal line voltage at which the thermometer is designed to operate; 100, 115, or 230V ac.

g. Connect a power cord between the transformer output and the thermometer ac line connector.

h. Set the thermometer front-panel controls as follows:

1. POWER switch to ON.

2. TEMP switch to °F or °C.

3. CHARGE switch to OFF.

i. Set the calibrator to zero volts output, 10 volt range, and turn it on.

## 4-19. Overload and Open Input

4-20. The following procedure tests the thermometer overload and open-circuit detectors:

a. Set the calibrator output to 10V dc. The thermometer display should begin to flash. While the display is lit, it should read the high end of the temperature range assigned to the compatible thermocouple type:

| | | | | |
|---|---|---|---|---|
| J | = | 1432° F | or | 778° C |
| K | = | 2472° F | or | 1356° C |
| T | = | 752° F | or | 400° C |
| E | = | 1832° F | or | 1000° C |
| R | = | 3232° F | or | 1778° C |
| S | = | 3232° F | or | 1778° C |
| B | = | 3352° F | or | 1844° C |
| C | = | 3999° F | or | 2328° C |

b. Set the calibrator output to OV dc.

c. Remove the input connections at the thermometer thermocouple input terminals. The display should begin to flash and read the low end of the temperature range except B which will display 32° F or 0° C. (Note: The low end of the B range is +533° C or +992° F).

| | | | | |
|---|---|---|---|---|
| J | = | -328° F | or | -200° C |
| K | = | -328° F | or | -200° C |
| T | = | -328° F | or | -200° C |
| E | = | -328° F | or | -200° C |
| R | = | 32° F | or | 0° C |
| S | = | 32° F | or | 0° C |
| B | = | 32° F | or | 0° C |
| C | = | 32° F | or | 0° C |

d. This completes the Overload and Open-Input test.

## 4-21. Line Voltage Regulation

4-22. Line voltage regulation is tested in conjunction with the accuracy test given in the following paragraphs. As the accuracy test is executed, vary the line voltage ± 10% with the variable line-power transformer to ensure the proper operation within the line-voltage limits.

## 4-23. Accuracy Test

4-24. The following procedure tests the accuracy of the thermometer:

a. Connect the voltage-divider leads to the thermocouple input terminals. Match polarity.

b. Refer to Table 4-3 and select the group of values that correspond to the thermocouple type used with the thermometer.

c. Sequentially, set the calibrator to obtain each of the divider output voltages listed within the selected group, and check the thermometer display against the appropriate display limits; 90-day or 1-year. Vary the ac voltage over the specified ± 10% operating range. Check to see that the thermometer is still reading within accuracy specifications.

d. Remove the voltage divider from the thermometer input.

e. Set the RJD switch to the operate position.

f. Install the thermometer in its case.

g. Connect a thermocouple of the appropriate type to the thermocouple input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

h. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath

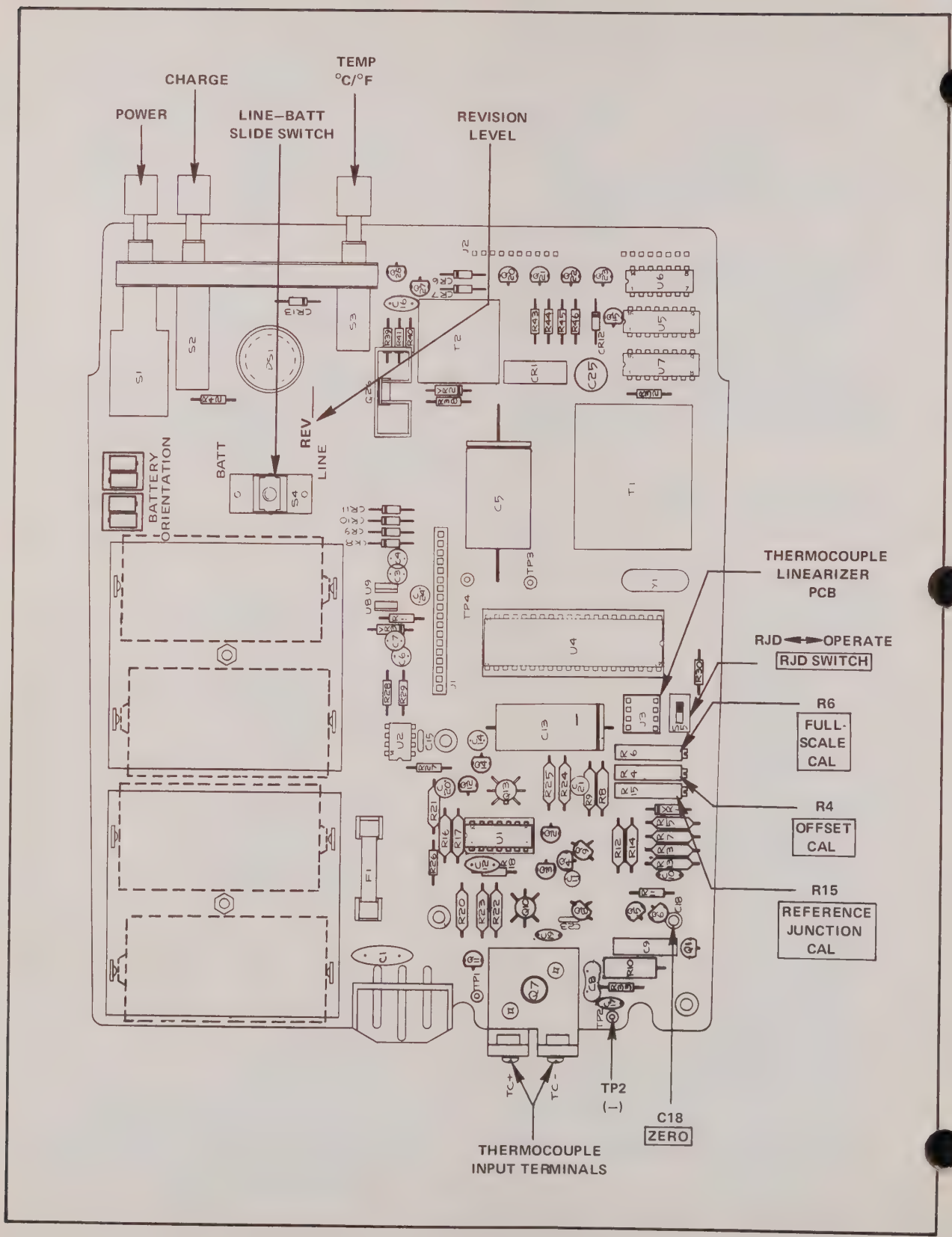



Figure 4-1. TEST POINT AND ADJUSTMENT LOCATIONS

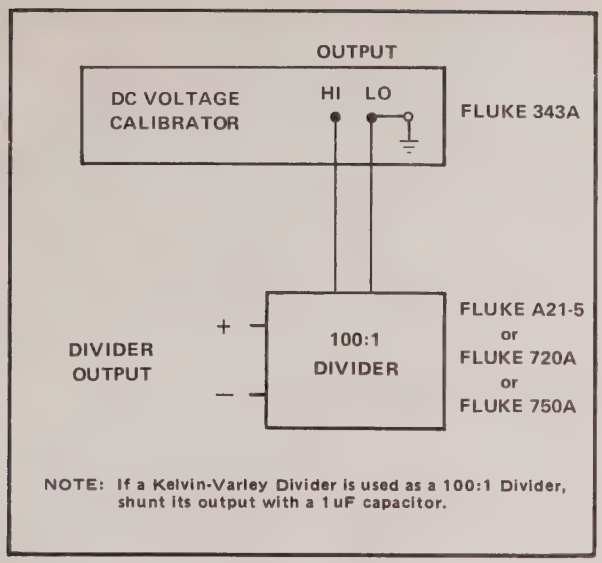



Figure 4-2. VOLTAGE DIVIDER–CALIBRATOR CONNECTION

construction. Two holes should be drilled in the thermos lid to provide a snug fit for the mercury thermometer and thermocouple probe.)

i. Refer to Table 4-4. Determine if the thermometer display is within the specified range of the lag-bath temperature reading.

*NOTE*

*Allow sufficient time for the mercury thermometer to come to a stable lag-bath temperature reading.*

j. This completes the accuracy test portion of the Performance Test.

## 4-25. Internal Temperature Rise

4-26. The following procedure measures the thermometer's internal temperature as sensed by the reference junction:

a. Connect a copper wire between the thermocouple

Table 4-3. TEMPERATURE ACCURACY

| TYPE | DIVIDER OUTPUT (mV dc) | °F DISPLAY LIMITS 90 DAY | °F DISPLAY LIMITS 1 YEAR | DIVIDER OUTPUT (mV dc) | °C DISPLAY LIMITS 90 DAY | °C DISPLAY LIMITS 1 YEAR |
|---|---|---|---|---|---|---|
| J | 42.640 | 1390.5 to 1393.5 | 1390 to 1394 | 42.640 | 754.6 to 756.6 | 754.1 to 757.1 |
| | 2.288 | 110.5 to 113.5 | 110 to 114 | 2.288 | 43.4 to 45.4 | 42.9 to 45.9 |
| | –1.643 | –30 to –26 | –30.5 to –25.5 | –2.175 | –45.9 to –42.9 | –45.9 to –42.9 |
| | –7.634 | –310 to –306 | –310.5 to –305.5 | –7.344 | –179.3 to –176.3 | –179.3 to –176.3 |
| K | 52.789 | 2389.5 to 2394.5 | 2389 to 2395 | 49.638 | 1220.7 to 1223.7 | 1220.2 to 1224.2 |
| | 2.709 | 149.5 to 154.5 | 149 to 155 | 6.363 | 154.1 to 157.1 | 153.6 to 157.6 |
| | –1.691 | –50.5 to –45.5 | –51 to –45 | –1.691 | –45.9 to –42.9 | –46.4 to –42.4 |
| | –5.713 | –310.5 to –305.5 | –311 to –305 | –5.510 | –179.3 to –176.3 | –179.8 to –175.8 |
| T | 20.188 | 730.5 to 733.5 | 730 to 734 | 19.497 | 376.8 to 378.8 | 376.8 to 378.8 |
| | 0.879 | 70.5 to 73.5 | 70 to 74 | 0.8789 | 21.2 to 23.2 | 21.2 to 23.2 |
| | –1.240 | –30 to –26 | –31.5 to –24.5 | –2.009 | –57.1 to –54.1 | –57.6 to –53.6 |
| | –5.421 | –310 to –306 | –311.5 to –304.5 | –5.221 | –179.3 to –176.3 | –179.8 to –175.8 |
| E | 74.694 | 1790 to 1794 | 1789.5 to 1794.5 | 74.694 | 976.8 to 978.8 | 976.3 to 979.3 |
| | 2.694 | 110 to 114 | 109.5 to 114.5 | 2.694 | 43.4 to 45.4 | 42.9 to 45.9 |
| | –1.897 | –30 to –26 | –31.5 to –24.5 | –3.080 | –57.1 to –54.1 | –57.6 to –53.6 |
| | –8.529 | –310 to –306 | –311.5 to –304.5 | –8.209 | –179.3 to –176.3 | –179.8 to –175.8 |
| R | 20.951 | 3188 to 3196 | 3187 to 3197 | 20.951 | 1753.1 to 1757.1 | 1752.6 to 1758.6 |
| | 0.259 | 108 to 116 | 107 to 117 | 0.259 | 41.9 to 46.9 | 41.4 to 47.4 |
| S | 18.321 | 3148.5 to 3155.5 | 3147.5 to 3156.5 | 17.295 | 1642.4 to 1646.4 | 1641.4 to 1647.4 |
| | 0.262 | 109.5 to 114.5 | 107.5 to 116.5 | 0.262 | 42.2 to 46.4 | 41.4 to 47.4 |
| B | 13.585 | 3268.5 to 3275.5 | 3267.5 to 3276.5 | 13.585 | 1798 to 1802 | 1797.5 to 1802.5 |
| | 1.535 | 1028.5 to 1035.5 | 1027.5 to 1036.5 | 1.661 | 575.8 to 579.8 | 575.3 to 580.3 |
| C | 35.875 | 3977 to 3987 | 3977 to 3988 | 35.875 | 2191 to 2197 | 2191 to 2197 |
| | 1.276 | 187 to 197 | 187 to 198 | .614 | 41 to 47 | 41 to 47 |

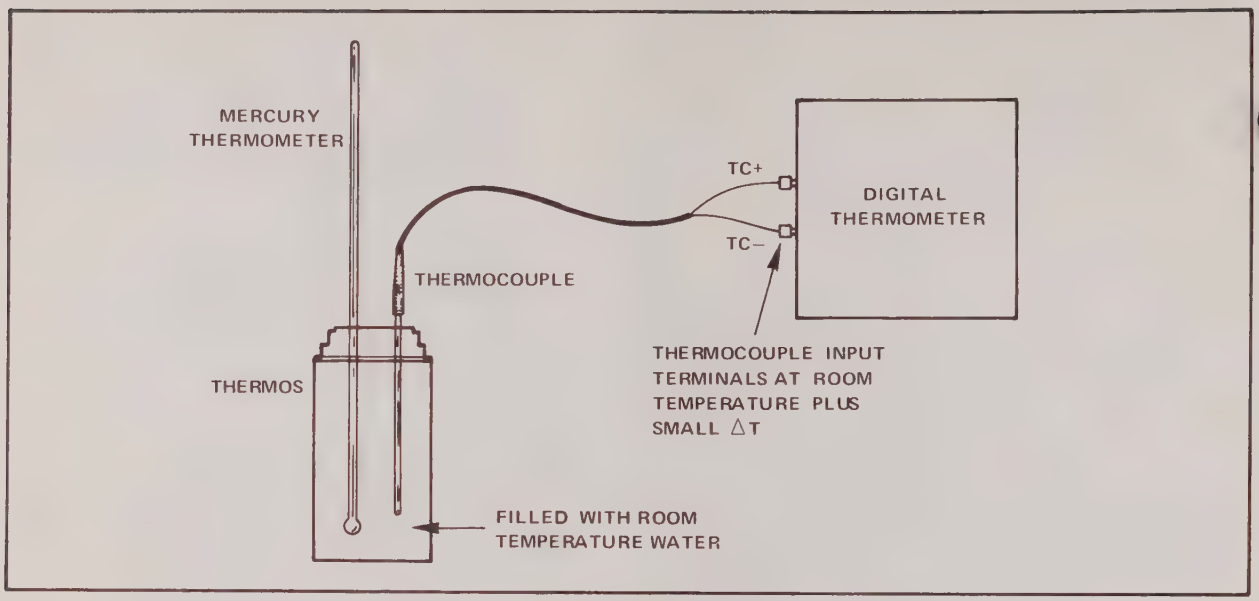



Figure 4-3. ROOM TEMPERATURE LAG BATH

input terminals (in place of the thermocouple leads used in the preceding test).

*NOTE*

*This procedure assumes that the thermometer has been energized for at least 30 minutes.*

b. Monitor the ambient temperature (room temperature) using a mercury thermometer near the back of the digital thermometer.

c. The digital thermometer will display the temperature of the internal reference junction. This temperature should not exceed the ambient temperature by more than 8° C (14.4° F).

Table 4-4. REFERENCE-JUNCTION ACCURACY LIMITS

| TYPE THERMOCOUPLE | °F | °C |
|---|---|---|
| J | +1.5° | +1.5° |
| K | +2.0° | +1.5° |
| T | +1.5° | +1.5° |
| E | +1.5° | +1.5° |
| R | +2.5° | +2.0° |
| S | +2.5° | +2.0° |
| C | +4.5° | +3.0° |
| The thermometer should read within the above limits for either the 90-day or 1-year check. | | |

d. Remove the short from the thermocouple input terminals.

e. This completes the test for internal temperature rise.

## 4-27. CALIBRATION

4-28. The thermometer should be calibrated every year or every 90 days, depending on the desired accuracy. Calibration should be performed also after the thermometer has been repaired or after the thermocouple linearizer (type-select) pcb has been changed.

4-29. Calibration of either the °F or °C scale, ensures the accuracy of both scales. Either scale can be verified after calibration by executing the accuracy portion of the Performance Test.

4-30. Interpolation of calibration setting for the °F scale is not necessary to obtain the specified performance accuracy. However, the °C scale requires interpolation of the calibration setting in order to obtain the specified performance. The following examples illustrate the difference.

4-31. °F example: For a K-type thermocouple, a voltage divider output of 52.789 mV is applied to the thermometer input. (See Table 4-5.) It is necessary only to set the calibration potentiometer to any setting that results in a digital display of 2392° F.

4-32. °C example: Calibration in °C is slightly more involved. For a K-type thermocouple, Table 4-5 shows that

49.638 mV are to be applied to the thermocouple input terminals. In order to calibrate to a required ± .25° C of the specified 1222.2° C, first adjust the potentiometer for a display flicker from 1221 to 1222. This locates the 1221.5°C position of the potentiometer. (The thermometer internally "rounds up" .5, .6, .7, .8, and .9 values, and drops .1, .2, .3 and .4). Next, count the number of turns, X, of the potentiometer to reach a display flicker from 1222 to 1223. This locates the 1222.5° C position of the potentiometer. Turn the potentiometer back .3X turns to locate the 1222.2° C position of the pot.

Table 4-5. FULL SCALE CALIBRATION

| PROBE TYPE | °F | | °C | |
|---|---|---|---|---|
| | DIVIDER OUTPUT (mV dc) | DISPLAY READING | DIVIDER OUTPUT (mV dc) | DISPLAY READING |
| J | +42.640 | 1392°F | +42.640 | 755.6°C |
| K | +52.789 | 2392°F | +49.638 | 1222.2°C |
| T | +20.188 | 732°F | +19.497 | 377.8°C |
| E | +74.694 | 1792°F | +74.694 | 977.8°C |
| R | +20.951 | 3192°F | +20.951 | 1755.6°C |
| S | +18.321 | 3152°F | +17.295 | 1644.4°C |
| B | +13.585 | 3272°F | +13.585 | 1800.0°C |
| C | +35.875 | 3982°F | +35.875 | 2194.4°C |

4-33. B-Type thermocouple calibration is different than that for other thermocouple types. A B-type thermocouple has no output at room temperature so does not require offset and reference-junction compensation for the equivalent thermocouple formed at the instrument input terminals. Therefore, to calibrate a B-type thermocouple, leave the RJD switch set to the operate position and execute only paragraphs 4-34, 4-35, 4-36 and 4-37, of the Calibration procedure; then reassemble the digital thermometer.

## 4-34. Calibration Procedure

4-35. SET-UP FOR CALIBRATION

a. Complete the equipment connections shown in Figure 4-2, by doing the following:

1. Connect the 100:1 divider specified in Table 4-1.

2. Apply power to the calibrator and turn it on. Allow sufficient warm-up time to assure calibration-output-voltage accuracy.

b. Remove the thermometer from its case. See paragraph 4-7.

c. Check the position of the battery-line switch. An instrument with no batteries should have the switch set to the LINE position. An instrument with batteries installed should have the switch set to the BATT position.

d. Locate the RJD switch on the main pcb. Set it to the RJD position. (This defeats the reference-junction circuitry.)

e. Connect a short length of copper wire between the thermocouple input terminals.

f. Connect the digital thermometer and calibrator to the appropriate line voltage(s).

g. Set the thermometer front panel controls as follows:

1. POWER switch to ON.

2. TEMP switch to °F or °C.

3. CHARGE switch to OFF.

4-36. ZERO ADJUSTMENT

a. Adjust C18 to obtain a steady or flashing 0 or –0 for the Celsius scale, or to obtain a steady 32 for the Fahrenheit scale.

4-37. FULL SCALE ADJUSTMENT

a. Determine the thermocouple compatible with the thermometer. The decal on the bottom of the thermometer case or the markings on the plug-in linearizer (type-select) pcb indicate the thermocouple type. (See Figure 4-1.)

b. Remove the short and connect the 100:1 divider output to the thermocouple input terminals. Match polarity.

c. Refer to Table 4-5 and set the calibrator output to obtain the voltage divider output specified for the compatible thermocouple type, for the degree scale being used.

d. Adjust the FULL-SCALE CAL potentiometer, R6 (Figure 4-1), to obtain the temperature display specified in Table 4-5.

e. This completes the calibration procedure for B-type thermocouples only.

4-38. OFFSET ADJUSTMENT

a. Set the RJD switch to the operate position.

b. Remove the divider leads from the thermocouple input terminals.

c. Short the thermocouple input terminals with a small piece of copper wire.

d. Remove the 100:1 divider from the calibrator output.

e. Set the calibrator to the 10V dc range.

f. Adjust the calibrator output to .5785V dc.

CAUTION!

**Be sure the voltage output of the calibrator is .5785V dc before proceeding to the next step. Improper voltage could damage the digital thermometer. Do not use the divider to obtain .5785V dc because the output impedance will create an error.**

g. Connect the positive lead from the calibrator to TC+, the positive thermocouple input terminal.

h. Connect the negative lead from the calibrator to Test Point 2. (TP2(–) in Figure 4-1).

i. Adjust the OFFSET CAL potentiometer, R4, for a temperature display of 77° or 25° C ± ¼ °C. (See Paragraph 4-30 on interpolation.)

j. Remove the calibrator output from the plus input terminal and TP2(–).

k. Remove the short at the thermocouple input terminals.

l. If the thermometer is being calibrated on a routine calibration cycle, or because of thermocouple type-change, this completes calibration. Reassemble the thermometer.

m. If the thermometer is being recalibrated because of repair or if reference-junction adjustment is desired, proceed with paragraph 4-39.

4-39. REFERENCE-JUNCTION ADJUSTMENT

a. Connect a compatible thermocouple probe to the input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

b. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction.)

c. Use an accurate mercury thermometer to monitor the temperature of the lag-bath. (See Table 4-1.)

d. Adjust the REFERENCE-JUNCTION CAL potentiometer, R15, to obtain a display that agrees with the lag-bath temperature.

e. Remove the thermocouple and reassemble the digital thermometer.

4-40. REFERENCE-JUNCTION BIAS-RESISTOR SELECTION

4-41. If the reference-junction transistor Q7 is replaced, then the reference-junction bias resistor R14 must also be replaced. This is a selected resistor which must be matched to Q7. To select the resistor:

a. Complete the calibration paragraphs 4-35 through 4-38.

b. Connect a compatible thermocouple probe to the input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S and C color coding.

c. Center the reference-junction pot R15.

d. Connect a decade resistance box that has ranges including 1K, 10K and 100K, in place of the reference-junction bias resistor R14. (See Table 4-1).

e. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction.)

f. Use an accurate mercury thermometer to monitor the temperature of the lag bath. (See Table 4-1.)

g. Adjust the decade resistance box for the value from Table 4-6 that causes the thermometer to read closest to lag-bath temperature. This will be the value of the reference-junction bias resistor R14.

h. Disconnect the decade box and install the selected R14.

i. Adjust the reference junction potentiometer so that the thermometer reading matches the lag-bath temperature.

Table 4-6. BIAS RESISTOR VALUES

| VALUE | JOHN FLUKE PART NUMBER | VALUE | JOHN FLUKE PART NUMBER |
|---|---|---|---|
| 49.9K | 268821 | 90.0K | 223537 |
| 52.3K | 237248 | 100K | 248807 |
| 54.9K | 271353 | 110K | 234708 |
| 57.6K | 289116 | 124K | 288407 |
| 60.4K | 291419 | 140K | 289439 |
| 63.4K | 235382 | 162K | 375998 |
| 68.1K | 236828 | 191K | 375923 |
| 73.2K | 237222 | 237K | 288373 |
| 78.7K | 289058 | 309K | 235283 |
| 84.5K | 229492 | 562K | 235358 |

j. Remove the thermocouple and reassemble the digital thermometer.

k. This completes the selection of R14. This also completes the calibration of the reference junction.

## 4-42. CALIBRATION TECHNIQUES

4-43. Calibration of the reference junction (R15) can be performed using any type of thermocouple except B-type. Once the reference junction has been calibrated for one type of thermocouple, it will be in calibration for use with any other thermocouple type. (Type B thermocouples do not use the reference junction due to their low output levels at room temperature.) Therefore, a calibration facility that maintains several digital thermometers which are configured for different thermocouple types, requires only one thermocouple probe and its corresponding linearizer (type-select) pcb in order to calibrate the reference junction of all of the instruments. A K-type thermocouple and linearizer pcb are recommended. The following procedure illustrates:

a. Calibrate the repaired thermometer with the K-type thermocouple and K-type linearizer pcb installed. Follow paragraphs 4-35 through 4-39. This calibrates the reference junction.

b. Change the thermometer to another type of thermocouple by changing the linearizer pcb and repeating paragraphs 4-35 through paragraph 4-38 only. These paragraphs do not require the actual thermocouple probe, but accomplish full-scale calibration for the non-K-type probe without disturbing the reference-junction calibration just set in a. above. This technique is especially useful in repair of an instrument that is normally used with a C-type thermocouple. C-types are expensive, the wire is brittle and the accuracy is relatively poor. The calibration facility can use the above technique rather than to stock C-type probes.

## 4-44. Thermocouple Accuracy Relating to the Reference-Junction Calibration Technique

4-45. The thermocouples specified in the list of calibration equipment meet specifications of ANSI Standard C96.1. The specifications for these probes can be as much as 4°F absolute error at or near room temperature. The first conclusion is that those probes could produce a calibration error of ± 4° F when used for calibrating the reference junction. This is an erroneous conclusion. Figure 4-3 illustrates the set-up for calibration. Figure 4-4A illustrates the reference-junction circuitry and Figure 4-4B illustrates the equivalent thermocouple circuit formed by the connection of the thermocouple to the input of the instrument. Note that in Figure 4-4B, the two thermocouple junctions formed at the input of the instrument (plus thermocouple wire (+TC) to the plus input terminal and the minus thermocouple wire (–TC) to the minus input terminal) can be represented as a single junction of +TC to –TC whose temperature is that of the input terminals of the instrument. The reference-junction circuitry senses the terminal temperature and generates a voltage that is equal to the voltage generated by the equivalent thermocouple formed at the input terminals referenced to ice point (See Figure 4-4A). For example, suppose the input terminals of the instrument and the attached probe are at the same temperature of 25° C. Since the thermocouple output voltage is proportional to the temperature between the two junctions, the output is zero volts. The reference-junction circuitry supplies a compensating voltage to the instrument such that the instrument will read 25° C. When calibrating the reference junction using the lag-bath technique, the reference junction is adjusted so that the instrument reads the lag-bath temperature. In using the lag-bath technique, there is only a small temperature difference, $\Delta T$, between the thermocouple junction in the probe and the equivalent thermocouple junction formed at the input terminals of the instrument. The voltage output across the thermocouple circuit is proportional to the temperature difference, $\Delta T$, between the two junctions. Hence, since $\Delta T$ is small, there is a small input voltage applied to the input of the instrument. This small input voltage will represent $\Delta T$ accurately to within less than .1° F. Therefore, when the reference junction is calibrated so that the instrument reads lag-bath temperature, the error introduced by the thermocouple will be less than .1° F.

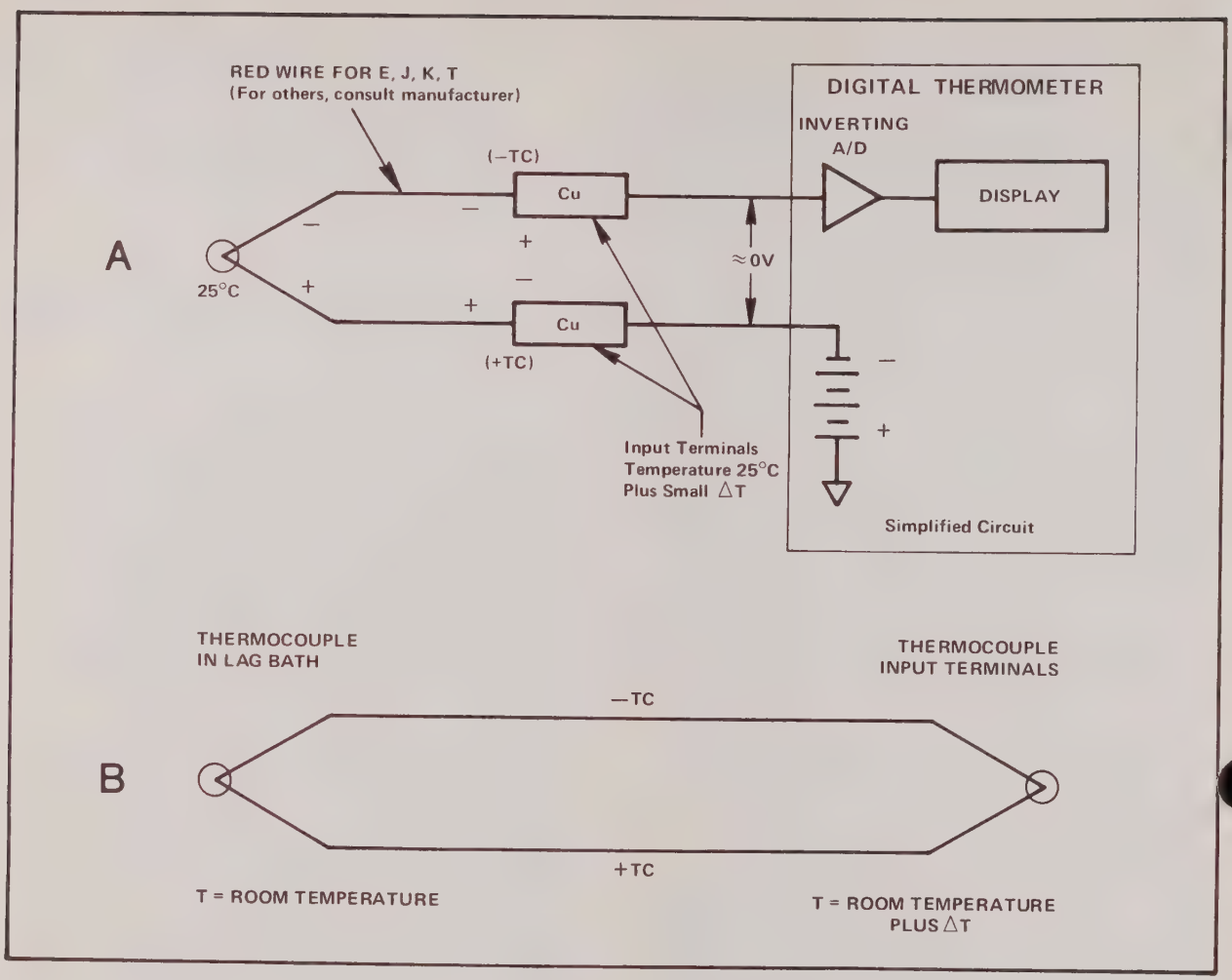



Figure 4-4. REFERENCE-JUNCTION COMPENSATION CIRCUITRY

## 4-46. Over-all Accuracy

4-47. The instrument will read very accurately around room temperature (See paragraph 4-44) but as the measured temperature increases or decreases from room temperature, the amount of thermocouple output deviation from NBS Standard 125, becomes the limiting factor in the accuracy of the instrument. If the thermocouple is in error by +4° F, at 900° F the display will be +4° F higher than if the thermocouple conformed perfectly to NBS Standard 125. Error specifications for the instrument do not include thermocouple probe inaccuracies. Those errors must be added to the instrument error in order to obtain an over-all accuracy figure.

## 4-48. TROUBLESHOOTING

4-49. A troubleshooting guide for the thermometer is given in Table 4-7. The guide is a simplified decision table and is recommended for use in isolating a problem to a functional circuit group. Details necessary to troubleshoot a fault in a functional circuit group can be derived from Section 3 Theory of Operation and Section 8 Schematic Diagrams.

Table 4-7. TROUBLESHOOTING GUIDE

| STEP | INSTRUCTION | IF YES GO TO | IF NO GO TO | GO TO |
|---|---|---|---|---|
| 1 | Energize the unit and connect a short across the thermocouple input terminals. | | | 2 |
| 2 | Does the display light? | 16 | 3 | |
| 3 | Is the power fuse blown? | 4 | 5 | |
| 4 | Replace fuse. | | | 2 |
| 5 | Are all power supply voltages present; +5, +6.8, +15 and −12V dc? | 7 | 22 | |
| 6 | Repair power supply. | | | 2 |
| 7 | Are Strobe Out pulses present at pins 9, 10, 11 and 12 of U4? (Use logic common as reference.) | 10 | 8 | |
| 8 | Is crystal operating? | 10 | 9 | |
| 9 | Replace crystal. | | | 2 |
| 10 | Are display drivers functioning? | 13 | 11 | |
| 11 | Is output data present at pins 4, 5, 6 and 7 of U4? | 12 | 13 | |
| 12 | Replace display drivers as necessary. | | | 2 |
| 13 | Are $\overline{\Delta 2}$, AZ, INT, DE+ or DE−, and CM present at U4? | 14 | 15 | |
| 14 | Display PCB defective. Repair as necessary. | | | 2 |
| 15 | U4 is defective. Replace. | | | 2 |
| 16 | Does display read approximate ambient temperature? | 21 | 17 | |
| 17 | Refer to Section 3 of this manual and use a scope to check for the presence of the waveforms shown in Figure 3-2. | | | 18 |
| 18 | Are all waveforms correct? | 20 | 19 | |
| 19 | Perform the necessary repairs to the analog circuit. | | | 17 |
| 20 | Calibrate the thermometer. | | | 21 |
| 21 | End. Thermometer is functional. | | | |
| 22 | Are you using line power? | 6 | 23 | |
| 23 | Are batteries installed? | 25 | 24 | |
| 24 | Install and charge Ni-Cad battery pack or operate from line power. | | | 1 |
| 25 | Is Line-Battery Slide-Switch (S4) set to BATT? (See Battery Installation, Paragraph 6-19.) | 26 | 27 | |
| 26 | Recharge or replace battery pack. | | | 1 |
| 27 | Set Line-Battery slide-switch to BATT. | | | 1 |

# PERFORMANCE TEST CHECKLIST

Fluke Model 2165A Digital Thermometer

Serial Number_____
Tested By:_____
Date:_____

## °F VERIFICATION TABLE (TEMPERATURE ACCURACY)

| PROBE TYPE | NOMINAL TEMPERATURE °F | 90 DAY | | | 1 YEAR | | |
|---|---|---|---|---|---|---|---|
| | | MIN. | ACTUAL | MAX. | MIN. | ACTUAL | MAX. |
| J | 1392 | 1390.5 | | 1393.5 | 1390 | | 1394 |
| | 112 | 110.5 | | 113.5 | 110 | | 114 |
| | −28 | −30 | | −26 | −30.5 | | −25.5 |
| | −308 | −310 | | −306 | −310.5 | | −305.5 |
| K | 2392 | 2389.5 | | 2394.5 | 2389 | | 2395 |
| | 152 | 149.5 | | 154.4 | 149 | | 155 |
| | −48 | −50.5 | | −45.5 | −51 | | −45 |
| | −308 | −310.5 | | −305.5 | −311 | | −305 |
| T | 732 | 730.5 | | 733.5 | 730 | | 734 |
| | 72 | 70.5 | | 73.5 | 70 | | 74 |
| | −28 | −30 | | −26 | −31.5 | | −24.5 |
| | −308 | −310 | | −306 | −311.5 | | −304.5 |
| E | 1792 | 1790 | | 1794 | 1789.5 | | 1794.5 |
| | 112 | 110 | | 114 | 109.5 | | 114.5 |
| | −28 | −30 | | −26 | −31.5 | | −24.5 |
| | −308 | −310 | | −306 | −311.5 | | −304.5 |
| R | 3192 | 3188 | | 3196 | 3187 | | 3197 |
| | 112 | 108 | | 116 | 107 | | 117 |
| S | 3152 | 3148.5 | | 3155.5 | 3147.5 | | 3156.5 |
| | 112 | 109.5 | | 114.5 | 107.5 | | 116.5 |
| B | 3272 | 3268.5 | | 3275.5 | 3267.5 | | 3276.5 |
| | 1032 | 1028.5 | | 1035.5 | 1027.5 | | 1036.5 |
| C | 3982 | 3977 | | 3987 | 3977 | | 3988 |
| | 192 | 187 | | 197 | 187 | | 198 |

Line Voltage Regulation _____ Passed ( ) Failed ( )

Accuracy Test _____ See Verification Tables

## °F VERIFICATION TABLE (REFERENCE JUNCTION ACCURACY)

| PROBE TYPE | 90-Day or 1-Year | |
|---|---|---|
| | Deviation Error From Room-Temperature Lag Bath | |
| | Maximum | Actual |
| J | ±1.5° | |
| K | ±2.0° | |
| T | ±1.5° | |
| E | ±1.5° | |
| R | ±2.5° | |
| S | ±2.5° | |
| C | ±4.5° | |

## PERFORMANCE TEST CHECKLIST, Cont.

Overload

Overrange . . . . . Passed ( ) Failed ( )

Open Circuit . . . . . Passed ( ) Failed ( )

Internal Temperature Rise . . . . . <8°C (14.4°F) above ambient

°C VERIFICATION TABLE (TEMPERATURE ACCURACY)

| PROBE TYPE | NOMINAL TEMPERATURE °C | 90 DAY | | | 1 YEAR | | |
|---|---|---|---|---|---|---|---|
| | | MIN. | ACTUAL | MAX. | MIN. | ACTUAL | MAX. |
| J | 755.4 | 754.6 | | 756.6 | 754.1 | | 757.1 |
| | 44.4 | 43.4 | | 45.4 | 42.9 | | 46.9 |
| | –44.4 | –45.9 | | –42.9 | –46.9 | | –42.9 |
| | 177.8 | –179.3 | | –176.3 | –179.3 | | –176.3 |
| K | 1222.2 | 1220.7 | | 1223.7 | 1220.2 | | 1224.2 |
| | 155.6 | 154.1 | | 157.1 | 153.6 | | 157.6 |
| | –44.4 | –45.9 | | –42.9 | –46.4 | | –42.4 |
| | –177.8 | –179.3 | | –176.3 | –179.8 | | –175.8 |
| T | 377.8 | 376.8 | | 378.8 | 376.8 | | 378.8 |
| | 22.2 | 21.2 | | 23.2 | 21.2 | | 23.2 |
| | –55.6 | –57.1 | | –54.1 | –57.6 | | –53.6 |
| | –177.8 | –179.3 | | –176.3 | –179.8 | | –175.8 |
| E | 977.8 | 976.3 | | 979.3 | 975.8 | | 979.8 |
| | 44.4 | 42.9 | | 45.9 | 42.4 | | 46.4 |
| | –55.6 | –57.1 | | –54.1 | –57.6 | | –53.6 |
| | –177.8 | –179.3 | | –176.3 | –179.8 | | –175.8 |
| R | 1755.6 | 1753.1 | | 1758.1 | 1752.6 | | 1758.6 |
| | 44.4 | 41.9 | | 46.9 | 41.4 | | 47.4 |
| S | 1644.4 | 1642.4 | | 1646.4 | 1641.4 | | 1647.4 |
| | 44.4 | 42.4 | | 46.4 | 41.4 | | 47.4 |
| B | 1800 | 1798 | | 1802 | 1797.5 | | 1802.5 |
| | 577.8 | 575.8 | | 579.8 | 575.3 | | 580.3 |
| C | 2194.4 | 2191 | | 2197 | 2191 | | 2197 |
| | 44.4 | 41 | | 47 | 41 | | 47 |

°C VERIFICATION TABLE (REFERENCE-JUNCTION ACCURACY)

| PROBE TYPE | 90-Day or 1-Year | |
|---|---|---|
| | Deviation Error From Room-Temperature Lag Bath | |
| | Maximum | Actual |
| J | ±1.5° | |
| K | ±1.5° | |
| T | ±1.5° | |
| E | ±1.5° | |
| R | ±2.0° | |
| S | ±2.0° | |
| C | ±3.0° | |

Section 5

# Lists of Replaceable Parts


| REFERENCE DESIGNATOR | ASSEMBLY NAME/NUMBER | PART NO. | PAGE |
|---|---|---|---|
| | Digital Thermometer, Final Assembly (2165A) . . . . . | ——— | 5-3 |
| A1 | Thermometer Assembly | | |
| | 100V (2165A-4001T-2) . . . . . | 434878 | 5-5 |
| | 115V (2165A-4001T) . . . . . | 422071 | 5-5 |
| | 230V (2165A-4001T) . . . . . | 422071 | 5-5 |
| A1A1 | Thermometer PCB Assembly (2165A-4001) . . . . . | 422089 | 5-6 |
| A2 | Display PCB Assembly (2165A-4003) . . . . . | 443515 | 5-10 |
| A3 | Type Select PCB Assembly . . . . . | ——— | 5-11 |

## 5-1. INTRODUCTION

5-2. This section contains an illustrated parts breakdown of the instrument. Components are listed alpha-numerically by assembly. Electrical components are listed by reference designation and mechanical components are listed by item number. Each listed part is shown in an accompanying illustration.

5-3. Parts lists include the following information:

a. Reference Designation or Item Number.

b. Description of each part.

c. Fluke Stock Number.

d. Federal Supply Code for Manufacturers. (See Appendix A for Code-to-Name list.)

e. Manufacturer's part Number or Type.

f. Total Quantity per assembly or component.

g. Recommended Quantity: This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc. that are not always part of the instrument, or are deviations from the basic instrument mode, the REC QTY column lists the recommended quantity of the item in that particular assembly.

h. Use Code is provided to identify certain parts that have been added, deleted or modified during production of the instrument. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity, paragraph 5-7.

## 5-4. HOW TO OBTAIN PARTS

5-5. Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from the John Fluke Mfg. Co., Inc. factory or authorized representative by using the FLUKE STOCK NUMBER. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

5-6. To ensure prompt and efficient handling of your order, include the following information.

a. Quality

b. FLUKE Stock Number

c. Description

d. Reference Designation or Item Number

e. Printed Circuit Board Part Number

f. Instrument model and Serial number

## 5-7. USE CODE EFFECTIVITY LIST

| USE CODE | SERIAL NUMBER EFFECTIVITY |
|---|---|
| A | 0123 to 50000 |
| B | 50000 and on. |
| C | Revision M* and previous (Approx. Ser. below 630,000) |
| D | Revision N* and later (Approx. Ser. 630,000 and up) |

* Revision Level inked on Thermometer PCB near S4 (See Figure 8-1).

Indicates MOS device which may be damaged by static discharge.

## FINAL ASSEMBLY, 2165A

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| | **DIGITAL THERMOMETER FINAL ASSEMBLY, 2165A** | | | | | | |
| A1 | Thermometer Assembly | | | | 1 | | |
| | 100V ac (2165A-4001T-2) | 434878 | 89536 | 434878 | | | |
| | 115V ac (2165A-4001T) | 422071 | 89536 | 422071 | | | |
| | 230V ac (2165A-4001T) | 422071 | 89536 | 422071 | | | |
| A2 | Display PCB Assembly (2165A-4003) | 443515 | 89536 | 443515 | 1 | | |
| A3 | Type Select PCB Assembly | | | | 1 | | |
| | One-of-eight possible type select pcb assemblies is supplied with the unit. | | | | | | |
| | R Type Select PCB Assembly (2160A-4012) | 415612 | 89536 | 415612 | | | |
| | S Type Select PCB Assembly (2160A-4013) | 415620 | 89536 | 415620 | | | |
| | B Type Select PCB Assembly (2160A-4014) | 415638 | 89536 | 415638 | | | |
| | C Type Select PCB Assembly (2160A-4015) | 415646 | 89536 | 415646 | | | |
| | J Type Select PCB Assembly (2160A-4016) | 415653 | 89536 | 415653 | | | |
| | K Type Select PCB Assembly (2160A-4017) | 415661 | 89536 | 415661 | | | |
| | T Type Select PCB Assembly (2160A-4018) | 415927 | 89536 | 415927 | | | |
| | E Type Select PCB Assembly (2160A-4019) | 415935 | 89536 | 415935 | | | |
| 1 | Adhesive | 436766 | 89536 | 436766 | 1 | | |
| 2 | Case, molded plastic | 427997 | 89536 | 427997 | 1 | | |
| 3 | Cord, ac line | | | | 1 | | |
| | 100 or 115V ac | 343723 | 89536 | 343723 | | | |
| | 230V ac | 343780 | 89536 | 343780 | | | |
| 4 | Decal, case bottom | 419093 | 89536 | 419093 | 1 | | |

## A1A1 THERMOMETER PCB ASSEMBLY

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| A1A1 | **THERMOMETER PCB ASSEMBLY (2165A-4001)** | 420089 | 89536 | 420089 | REF | | |
| | **Figure 8-1** | | | | | | |
| C1 | Cap, cer, .01 uF ±20%, 3kV | 266320 | 56289 | 41C301A2 | 1 | | |
| C3,C4 | Cap, Ta, 6.8 uF ±20%, 35V | 363713 | 56289 | 196D685X0035 KA1 | 2 | | |
| C5 | Cap, elect, 4000 uF +100/−10%, 10V | 330761 | 25088 | B41010-4700/10 | 1 | 1 | |
| C6,C7, C14, C20, C21, C24 | Cap, Ta, 10 uF ±20%, 20V | 330662 | 56289 | 196D106X0020 JA1 | 6 | | |
| C8 | Cap, mica, 100 pF ±1%, 500V | 226126 | 71234 | DM15F100F | 1 | | |
| C9 | Cap mylar, 0.47 uF ±10%, 100V | 369124 | 73445 | C280MAH/A47 0K | 1 | | |
| C10 | Cap, disc, 100 pF ±10%, 1kV | 105593 | 71590 | DD101 | 1 | | |
| C11 | Cap, Ta, 2.2 uF ±10%, 15V | 364216 | 56289 | 196D222X9015 HA1 | 1 | | |
| C12 | Cap, cer, .025 uF ±20%, 100V | 168435 | 56289 | C023B101H253M | 1 | | |
| C13 | Cap, polypro, 0.47 uF ±10%, 50V | 363085 | 89536 | JF86 | 1 | | |
| C15 | Cap, cer, 2700 pF ±20%, 100V | 362889 | 72982 | 8121-A100-W5R-272M | 1 | | |
| C16 | Cap, cer, .0012 uF ±10%, 500V | 106732 | 71590 | CF122 | 1 | | |
| C17, C19 | Cap, cer, 1000 pF ±10%, 500V | 357806 | 56289 | C106B102G102K | 2 | | |
| C18 | Cap, var, .25 - 1.5 pF, 2kV | 218206 | 72982 | 530-000 | 1 | | |
| C23 | Cap, cer, 1 pF, ±0.25 pF, 100V | 436477 | 72982 | 8101-A100-C0G-109G | 1 | | |
| CR1 | Diode, bridge rectifier | 392910 | 89536 | 392910 | 1 | 1 | |
| CR6 thru CR11 | Diode, Si, 150 mA, 75V | 203323 | 09214 | 1N4448 | 6 | 2 | |
| CR12, CR13 | Diode, Si, rect | 343491 | 04713 | 1N4002 | 2 | 1 | |
| DS1 | Lamp | 342237 | 06001 | TYPE 63 | 1 | 1 | |

## A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| F1 | Fuse, slo-blo, 1/8A | 166488 | 71400 | MDL 1-8 | 1 | 5 | |
| J1 | Connector, female, 18-pin | 435024 | 00779 | 583773-8 | 1 | | |
| Q1 thru Q6,Q8, Q9, Q12, Q14 | Xstr, J-FET, N-channel | 343830 | 89536 | 343830 | 10 | 2 | |
| Q7 | Xstr, Si, NPN | 329698 | 07263 | 2N2484 | 1 | 1 | |
| Q10 | Xstr, FET, dual N-channel | 439703 | 89536 | 439703 | 1 | 1 | |
| Q11, Q15 | Xstr, Si, NPN | 218396 | 04713 | 2N3904 | 1 | 1 | |
| Q13 | Xstr, FET, dual N-channel | 379321 | 89536 | 379321 | 1 | 1 | |
| Q20 thru Q23 | Xstr, Si, NPN | 381798 | 04713 | MPS-A-13 | 4 | 1 | |
| Q26 | Xstr, Si, NPN | 418459 | 01295 | T1P-31 | 1 | 1 | |
| Q27, Q28 | Xstr, Si, NPN | 272237 | 07263 | 2N4946 | 2 | 1 | |
| R1 | Res, comp, 430 ±5%, ½W | 109058 | 01121 | EB4315 | 1 | | |
| R3 | Res, mf, 15.8k ±1%, 1/8W | 293688 | 91637 | MFF1-81582F | 1 | | |
| R4, R6 | Res, var, 25k ±20%, ½W | 285213 | 71450 | 190PC253B | 2 | 1 | |
| R5 | Res, mf, 261k ±1%, 1/8W | 257535 | 91637 | MFF1-82613F | 1 | | |
| R7 | Res, mf, 187k, ±1%, 1/8W | 257469 | 91637 | MFF1-81873F | 1 | | |
| R8 | Res, mf, 2k ±0.1%, 1/8W | 340174 | 91637 | MFF1-82001BS | 1 | | |
| R9 | Res, mf, 1k ±0.1%, 1/8W | 340380 | 91637 | MFF1-81001BS | 1 | | |
| R10 | Res, comp, 47k ±5%, 1W | 150219 | 01121 | GB4735 | 1 | | |
| R11, R29 | Res, comp, 1M ±5%, ¼W | 182204 | 01121 | CB1055 | 2 | | |
| R12 | Res, mf, 26.7k ±0.1%, 1/8W | 344465 | 91637 | MFF1-82672BS | 1 | | |
| R13 | Res, mf, 150k ±1%, 1/8W | 241083 | 91637 | MFF1-81503F | 1 | | |
| R15 | Res, var, 50k ±20%, ½W | 330688 | 71450 | 190PC503B | 1 | 1 | |

## A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| R16, R17 | Res, mf, 14.7k ±1%, 1/8W | 226225 | 91637 | MFF1-81472F | 2 | | |
| R18 | Res, comp, 470 ±5%, ¼W | 147983 | 01121 | CB4715 | 1 | | |
| R20 | Res, mf, 28.7k ±1%, 1/8W | 235176 | 91637 | MFF1-82872F | 1 | | |
| R21 | Res, mf, 61.9k ±1%, 1/8W | 237230 | 91637 | MFF1-86192F | 1 | | |
| R22 | Res, mf, 19.1k ±1%, 1/8W | 234963 | 91637 | MFF1-81912F | 1 | | |
| R23 | Res, mf, 1k ±1%, 1/8W | 168229 | 91637 | MFF1-81001F | 1 | | |
| R24, R25 | Res, mf, 82.5k ±1%, 1/8W | 246223 | 91637 | MFF1-88252F | 1 | | |
| R26 | Res, comp, 680k ±5%, ¼W | 188433 | 01121 | CB6845 | 1 | | |
| R27 | Res, comp, 100 ±5%, ¼W | 147926 | 01121 | CB1015 | 1 | | |
| R28, R33 | Res, comp, 220k ±5%, ¼W | 160937 | 01121 | CB2245 | 2 | | |
| R30, R32 | Res, comp, 20k ±5%, ¼W | 221614 | 01121 | CB2035 | 2 | | |
| R38 | Res, comp, 68 ±5%, ¼W | 147918 | 01121 | CB6805 | 1 | | |
| R39 | Res, comp, 2k ±5%, ¼W | 202879 | 01121 | CB2025 | 1 | | |
| R40 | Res, comp, 22 ±5%, ¼W | 147884 | 01121 | CB2205 | 1 | | |
| R41 | Res, comp, 330 ±5%, ¼W | 147967 | 01121 | CB3315 | 1 | | |
| R42 | Res, comp, 9.1 ±5%, ½W | 218768 | 01121 | EB9R105 | 1 | | |
| R43 thru R46 | Res, comp, 27k ±5%, ¼W | 148148 | 01121 | CB2735 | 4 | | |
| S1, S2, S3 | Switch Assembly, push button | 428490 | 89536 | 428490 | 1 | 1 | |
| S4 | Switch, slide, 4-pdt | 428615 | 82389 | 53212L | 1 | 1 | C |
| S4 | Switch, slide, 4-pdt | 453985 | 95146 | CST042N | 1 | 1 | D |
| S5 | Switch, slide, dpdt | 423129 | 95146 | SLS-220-1 | 1 | 1 | |
| T2 | Xfmr, inverter | 436097 | 89536 | 436097 | 1 | | |
| U1 | IC, dual opnl ampl | 404087 | 49956 | RC4739DP | 1 | 1 | |
| U2 | IC, opnl ampl | 352195 | 49956 | RC311DN | 1 | 1 | |
| U5 | IC, TTL, bcd-to-7 segment decoder/driver | 340109 | 01295 | SN7447 | 1 | 1 | |
| U6 | IC, res network, 60Ω | 344069 | 89536 | 344069 | 1 | 1 | |

## A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| U7 | IC, C-MOS, Hex Buffer/Inverter ⊗ | 381830 | 02735 | CD4050AE | 1 | 1 | |
| U8 | IC, linear, voltage regulator, +15V | 413187 | 12040 | LM340T-18 | 1 | 1 | |
| U9 | IC, linear, voltage regulator −12V | 381665 | 04713 | MC7912CP | 1 | 1 | |
| VR1 | Diode, zener, 6.4V ±2% | 393579 | 04713 | 1N4567 | 1 | 1 | |
| VR2 | Diode, zener, 6.2V | 325811 | 07910 | 1N753A | 1 | 1 | |
| VR3 | Diode, zener, 6.8V | 260695 | 07910 | 1N754A | 1 | 1 | |
| Y1 | Crystal, 400 kHz | 403352 | 89536 | 403352 | 1 | | |
| 1 | Button, dark gray | 419689 | 89536 | 419689 | 1 | | |
| 2 | Button, light gray | 412163 | 89536 | 412163 | 1 | | |
| 3 | Button, green | 419747 | 89536 | 419747 | 1 | | |
| 4 | Connector, ac line | | | | | | |
| | Contact, ground | 338640 | 89536 | 338640 | 1 | | |
| | Contact, voltage | 338657 | 89536 | 338657 | 2 | | |
| | Insulator, paper | 344184 | 89536 | 344184 | 1 | | |
| | Insulator, plastic | 338624 | 89536 | 338624 | 1 | | |
| 5 | Holder Assembly, Battery | | | | | | |
| | Contacts, battery | 344200 | 89536 | 344200 | 8 | | |
| | Holder, battery | 390450 | 89536 | 390450 | 4 | | |
| | Hold down, battery | 347427 | 89536 | 347427 | 2 | | |
| 6 | Isothermal Block | | | | | | |
| | Insulator | 415695 | 89536 | 415695 | 1 | | |
| | Plate, terminal, neg | 415687 | 89536 | 415687 | 1 | | |
| | Plate, terminal, pos. | 415679 | 89536 | 415679 | 1 | | |
| 7 | Socket, IC, 40-pin | 418988 | 91506 | 340-AG37D | 1 | | |
| 8 | Heatsink | 428805 | 89536 | 428805 | 1 | | |

## A2 DISPLAY PCB ASSEMBLY

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| A2 | **DISPLAY PCB ASSEMBLY (2165A-4003)** **Figure 8-3** | 443515 | 89536 | 443515 | REF | | |
| DS1, DS2 | LED, dual 7-segment character display | 419051 | 29083 | MAN 6610 | 2 | 1 | A |
| DS3 | LED, 7-segment character display | 407874 | 29083 | MAN 4610 | 1 | 1 | A |
| DS1 thru DS5 | LED, 7-segment, numeric display | 418012 | 28480 | 5082-7651 | 5 | 1 | B |
| P4 | Connector, female, 16-pin | 375329 | 00779 | 85863-3 | 1 | | |
| R1 | Res, comp, 91 ±5%, 1/4W | 221887 | 01121 | CB9105 | 1 | | |

## A3 TYPE SELECT PCB ASSEMBLY

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| A3 | **TYPE SELECT PCB ASSEMBLY** | | | | REF | | |
| | **Figure 8-5** | | | | | | |
| | R Type (2160A-4012) | 415612 | 89536 | 415612 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 324 ±1%, 1/8W | 423780 | 91637 | MFF1-83240F | 1 | | |
| R2 | Res, mf, 69.5 ±0.1%, 1/8W | 423756 | 91637 | MFF1-869R5B | 1 | | |
| | S Type (2160A-4013 | 415620 | 89536 | 415620 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 324 ±1%, 1/8W | 423780 | 91637 | MFF1-83240F | 1 | | |
| R2 | Res, mf 70 ±0.1%, 1/8W | 423764 | 91637 | MFF1-8A700F | 1 | | |
| | B Type (2160A-4014) | 415638 | 89536 | 415638 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 143 ±1%, 1/8W | 423699 | 91637 | MFF1-81430F | 1 | | |
| | C Type (2160A-4015) | 415646 | 89536 | 415646 | 1 | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 590 ±1%, 1/8W | 446625 | 91637 | MFF1-85910F | 1 | | |
| R2 | Res, mf, 164.3 ±0.1%, 1/8W | 424564 | 91637 | MFF1-8164R3B | 1 | | |
| | J Type (2160A-4016) | 415653 | 89536 | 415653 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 10.7k ±1%, 1/8W | 423681 | 91637 | MFF1-81072F | 1 | | |
| R2 | Res, mf, 619 ±0.1%, 1/8W | 423715 | 91637 | MFF1-86190B | 1 | | |
| | K Type (2160A-4017) | 415661 | 89536 | 415661 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 3.74k ±1%, 1/8W | 260547 | 91637 | MFF1-83741F | 1 | | |
| R2 | Res, mf, 481.4 ±0.1%, 1/8W | 423723 | 91637 | MFF1-8481R4 | 1 | | |

## A3 TYPE SELECT PCB ASSEMBLY (Cont.)

| REF DESIG OR ITEM NO. | DESCRIPTION | FLUKE STOCK NO. | MFG FED SPLY CDE | MFG PART NO. OR TYPE | TOT QTY | REC QTY | USE CDE |
|---|---|---|---|---|---|---|---|
| | T Type (2160A-4018) | 415927 | 89536 | 415927 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 3.74k ±1%, 1/8W | 260547 | 91637 | MFF1-83741F | 1 | | |
| R2 | Res, mf, 483.7 ±0.1%, 1/8W | 423731 | 91637 | MFF1-8483R7B | 1 | | |
| | E Type (2160A-4019) | 415935 | 89536 | 415935 | | | |
| P3 | Socket, IC, 8-pin | 418608 | 00779 | 583640-1 | 1 | | |
| R1 | Res, mf, 53.6k ±1%, 1/8W | 291401 | 91637 | MFF1-85362F | 1 | | |
| R2 | Res, mf, 732 ±0.1%, 1/8W | 423749 | 91637 | MFF1-87320B | 1 | | |

Section 6

# Option & Accessory Information

## 6-1. INTRODUCTION

6-2. This section of the manual contains information concerning the Options and Accessories available for use with the Model 2165A Digital Thermometer. The first portion of this section provides a brief description of each option and accessory. The depth of detail is intended to give the prospective user an adequate first aquaintance with the features and capabilities of each. Detailed information concerning specifications, operating instructions, maintenance, list of replaceable parts and schematics is supplied separately with some options and accessories, and is designed to comprise the second portion of this section. Unique page and paragraph numbering is assigned to each of the add-on descriptions to allow separation into easily identifiable subsections. The material is prepunched (T-punched) to permit insertion without disassembling the manual. Table 6-1 lists the available options and accessories and defines the manner in which each is documented.

Table 6-1. 2165A OPTIONS, ACCESSORIES AND DOCUMENTATION SOURCES

| MODEL OR OPTION NO. | DESCRIPTION | DOCUMENTATION SUPPLIED | |
|---|---|---|---|
| | | WITH UNIT | HERE IN |
| C80 | Carrying Case | | ● |
| C86 | Carrying Case | | ● |
| P20J | J-Type TC Probe | | ● |
| P20K | K-Type TC Probe | | ● |
| P20T | T-Type TC Probe | | ● |
| M00-100-714 | Front Panel Dust Cover | | ● |
| M00-200-611 | Rack Mtg. Kit, Offset | ● | |
| M00-200-612 | Rack Mtg. Kit, Center | ● | |
| M00-200-613 | Rack Mtg. Kit, side-by-side | ● | |
| 2160A-7016 | J-Type Select PCB | | ● |
| 2160A-7017 | K-Type Select PCB | | ● |
| 2160A-7019 | E-Type Select PCB | | ● |
| 2160A-7018 | T-Type Select PCB | | ● |
| 2160A-7012 | R-Type Select PCB | | ● |
| 2160A-7013 | S-Type Select PCB | | ● |
| 2160A-7014 | B-Type Select PCB | | ● |
| 2160A-7015 | C-Type Select PCB | | ● |
| 2160A-7022 | Interface Cable | | ● |
| –01 | Battery Pack | | ● |
| –02 | Digital Output Unit | ○ | |
| –04 | Analog Output Unit | ○ | |

○ = T-punched for insertion in Section 6 of this manual.
● = Not T-punched.

## 6-3. CARRYING CASE (C80)

6-4. The Model C80 Carrying Case, Figure 6-1, is a soft vinyl plastic container designed for the storage and transport of the 2165A. The case provides the unit with adequate protection against normal handling and storage conditions. In addition to a shoulder strap, the C80 is equipped with a storage compartment for probes, power cord, and other compact accessories.

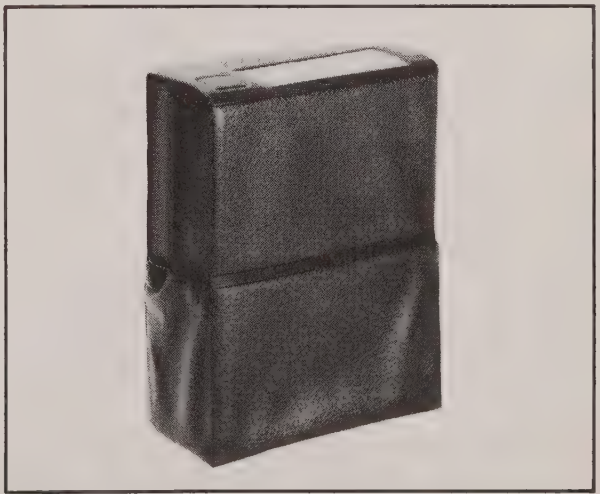


Figure 6-1. C80 CARRYING CASE

## 6-5. CARRYING CASE (C86)

6-6. The Model C86 Carrying Case, Figure 6-2, is a molded polyethylene container, with handle, designed for use in transporting the 2165A. This rugged case provides the unit with maximum protection against rough handling and adverse weather conditions. A separate storage compartment is provided for probes, power cord, and other compact accessories.

Figure 6-2. C86 CARRYING CASE

## 6-7. THERMOCOUPLE PROBES

6-8. Three types of thermocouple probe assemblies (J, K and T) are available from Fluke for use with the 2165A. See Table 6-1. Each thermocouple is enclosed in a 6-inch x 1/8 inch iconel sheath, and includes a heavy duty transition splice and spring. See Figure 6-3. The thermocouple junction is grounded to the sheath, and 36-inch trimmed leads are included on all units. Refer to the Tables under Specifications in Section 1 of this manual for the temperature ranges recommended for each thermocouple type.

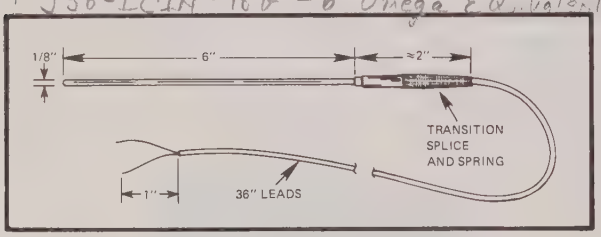



Figure 6-3. P20 SERIES PROBE

## 6-9. FRONT PANEL DUST COVER (M00-100-714)

6-10. The front panel dust cover is a molded plastic snap-on accessory which fits over the front panel of the 2165A. The dust cover provides protection for the front panel controls, and is useful when storing or transporting the unit.

## 6-11. RACK MOUNTING KITS

6-12. Three rack mounting kits are available for mounting the 2165A in a standard 19-inch equipment rack. The kits, listed in Table 6-1, provide the option of either offset mounting (left/right), center mounting or side-by-side mounting.

## 6-13. TYPE SELECT PCB's

6-14. A series of plug-in type select pcb's are available as accessories to allow the thermocouple compatibility of the 2165A to be changed by the user. The available pcb's are listed in Table 6-1; and the instructions necessary to interchange pcb's in the 2165A are given in Section 2 of this manual under Thermocouple Compatibility. Only one of the pcb's can be installed in the 2165A at any given time.

## 6-15. BATTERY PACK, OPTION –01

6-16. Battery operation of the 2165A requires the installation of four, rechargeable, D-size, Nickel-Cadmium batteries. These batteries are field installable and are available from the John Fluke Mfg. Co., Inc. as the –01 Option. A charging circuit is included in the basic 2165A to charge the batteries. The batteries receive a trickle-charge during normal operation and a fast-charge when the Charge Mode is enabled. Typically, a fully charged set of batteries will allow 8 hours of portable operation. To fully charge a set of discharged batteries, operate the unit in the ON charge mode for 14 hours at a case temperature below 25°C (77°F). (See paragraph 6-23.)

**CAUTION!**

**The 2165A may be damaged if alkaline, zinc-carbon, or mercury batteries are charged in the unit. Use only Nickel-Cadmium batteries.**

### 6-17. Installation

6-18. Use the following procedure for installing Ni-Cad batteries in the 2165A:

a. Disconnect line cord. Remove center retaining screw at rear of instrument case, and remove instrument from case.

b. Remove center bolt and nut from each battery holder.

c. Remove the top half of each plastic holder.

d. Orient the battery polarities according to the picture printed on the thermometer pcb (see Figure 4-2).

e. Reinstall plastic battery holders.

f. Set LINE-BATT slide-switch to BATT (see Figure 4-2).

g. Reinstall instrument in case.

## 6-19. Charging Ni-Cad Batteries

*NOTE*

*Battery manufacturers recommend that Ni-Cad batteries be recharged at least every 90 days. Storage and charging temperatures below +25°C (77°F) are recommended to achieve full charge and 8 hours of portable operation.*

6-20. With regard to the charging of Nickel-Cadmium batteries, there are some phenomena which should be considered. For instance, charging Ni-Cad batteries with cell case temperatures above 25°C will cause the cell's charge capacity to decrease. The decrease in capacity is linear from 100% of rated capacity at 25°C to only 60% of rated capacity at 50°C, and as low as 45% at 60°C. Cell case temperatures typically run from 5°C to 10°C above ambient temperature during charging due to heat dissipated by the charging circuit.

6-21. Charge capacity may also be affected by a cell's charging-discharging routine, due to a memory-type phenomenon. For instance, if a Ni-Cad battery pack is used in a daily routine where it is allowed to discharge by only 30% before being fully recharged again, it will eventually become a battery pack capable of delivering only 30% of its rated capacity. To return such a battery pack to its rated capacity, connect an external load which will discharge the battery completely at a rate equal to its capacity divided by 20. For example, a pack of four series-connected 1.2 volt cells having individual capacity ratings of 3.5 ampere hours should be discharged at a rate of 3.5A ÷ 20 = .175A. This requires a load resistor of 4.8V ÷ .175A = 27.5 ohms (approximate) with a power rating of at least (4.8V) (.175A) = .85W. (A 2-watt carbon composition resistor is suitable.)

6-22. Allow the battery pack to discharge for 30 hours, then charge the battery pack at twice the discharge rate for 20 hours. (In the example, the charging rate would be 0.35 amperes at 4.8 volts.) When charging is complete, discharge the pack at the capacity-divided-by-20 rate for 30 hours, then recharge at twice the discharge rate for a period of 20 hours. The battery pack should now be restored to its rated capacity.

## 6-23. DIGITAL OUTPUT UNIT, OPTION –02

*NOTE*

*The Digital Output Unit is functional only when the 2165A is being operated from line power.*

6-24. The Digital Output Unit (Option –02) is a field installable pcb that mounts on the interior of the 2165A and provides a digital output which is equivalent to the displayed measurement data. The digital output is positive-true, TTL compatible and is presented in bcd, character-parallel format. All displayed characters are represented at the output. Output data is solicited by an External Trigger input and valid data is ensured by Busy and $\overline{\text{Busy}}$ outputs.

6-25. External connections to the Digital Output Unit are made through a 34-pin cable which is supplied with the pcb.

## 6-26. ANALOG OUTPUT UNIT, OPTION –04

*NOTE*

*The Analog Output Unit is functional only when the 2165A is being operated from line power.*

6-27. The Analog Output Unit is a field installable pcb assembly which provides the 2165A with a rear-panel analog output voltage proportional to the displayed measurement data. The output voltage is electrically isolated from the 2165A and covers a voltage range of –0.4 to +4V dc. Automatic polarity sensing is provided for both °C and °F measurements to ensure that the polarity of the output voltage agrees with the displayed polarity. Since the analog output terminals are isolated from the 2165A, the output voltage is referenced to the low terminal of the external recording device (voltmeter, strip-chart recorder, etc.).

6-28. External connections to the Analog Output Unit are made through a connector and cable which is supplied with the pcb.

# Section 7
# General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5.

## List of Abbreviations and Symbols

| | |
|---|---|
| **A or amp** | ampere |
| **ac** | alternating current |
| **af** | audio frequency |
| **a/d** | analog-to-digital |
| **assy** | assembly |
| **AWG** | american wire gauge |
| **B** | bel |
| **bcd** | binary coded decimal |
| **°C** | Celsius |
| **cap** | capacitor |
| **ccw** | counterclockwise |
| **cer** | ceramic |
| **cermet** | ceramic to metal(seal) |
| **ckt** | circuit |
| **cm** | centimeter |
| **cmrr** | common mode rejection ratio |
| **comp** | composition |
| **cont** | continue |
| **crt** | cathode-ray tube |
| **cw** | clockwise |
| **d/a** | digital-to-analog |
| **dac** | digital-to-analog converter |
| **dB** | decibel |
| **dc** | direct current |
| **dmm** | digital multimeter |
| **dvm** | digital voltmeter |
| **elect** | electrolytic |
| **ext** | external |
| **F** | farad |
| **°F** | Fahrenheit |
| **FET** | Field-effect transistor |
| **ff** | flip-flop |
| **freq** | frequency |
| **FSN** | federal stock number |
| **g** | gram |
| **G** | giga ($10^9$) |
| **gd** | guard |
| **Ge** | germanium |
| **GHz** | gigahertz |
| **gmv** | guaranteed minimum value |
| **gnd** | ground |
| **H** | henry |
| **hd** | heavy duty |
| **hf** | high frequency |
| **Hz** | hertz |
| **IC** | integrated circuit |
| **if** | intermediate frequency |
| **in** | inch(es) |
| **intl** | internal |
| **I/O** | input/output |
| **k** | kilo ($10^3$) |
| **kHz** | kilohertz |
| **kΩ** | kilohm(s) |
| **kV** | kilovolt(s) |
| **lf** | low frequency |
| **LED** | light-emitting diode |
| **LSB** | least significant bit |
| **LSD** | least significant digit |
| **M** | mega ($10^6$) |
| **m** | milli ($10^{-3}$) |
| **mA** | milliampere(s) |
| **max** | maximum |
| **mf** | metal film |
| **MHz** | megahertz |
| **min** | minimum |
| **mm** | millimeter |
| **ms** | millisecond |
| **MSB** | most significant bit |
| **MSD** | most significant digit |
| **MTBF** | mean time between failures |
| **MTTR** | mean time to repair |
| **mV** | millivolt(s) |
| **mv** | multivibrator |
| **MΩ** | megohm(s) |
| **n** | nano ($10^{-9}$) |
| **na** | not applicable |
| **NC** | normally closed |
| **(–) or neg** | negative |
| **NO** | normally open |
| **ns** | nanosecond |
| **opnl ampl** | operational amplifier |
| **p** | pico ($10^{-12}$) |
| **para** | paragraph |
| **pcb** | printed circuit board |
| **pF** | picofarad |
| **pn** | part number |
| **(+) or pos** | positive |
| **pot** | potentiometer |
| **p-p** | peak-to-peak |
| **ppm** | parts per million |
| **PROM** | programmablle read-only memory |
| **psi** | pound-force per square inch |
| **RAM** | random-access memory |
| **rf** | radio frequency |
| **rms** | root mean square |
| **ROM** | read-only memory |
| **s or sec** | second (time) |
| **scope** | oscilloscope |
| **SH** | shield |
| **Si** | silicon |
| **semo** | serial number |
| **sr** | shift register |
| **Ta** | tantalum |
| **tb** | terminal board |
| **tc** | temperature coefficient or temperature compensating |
| **tcxo** | temperature compensated crystal oscillator |
| **tp** | test point |
| **u or μ** | micro ($10^{-6}$) |
| **uhf** | ultra high frequency |
| **us or μs** | microsecond(s) ($10^{-6}$) |
| **uut** | unit under test |
| **V** | volt |
| **v** | voltage |
| **var** | variable |
| **vco** | voltage controlled oscillator |
| **vhf** | very high frequency |
| **vlf** | very low frequency |
| **W** | watt(s) |
| **ww** | wire wound |
| **xfmr** | transformer |
| **xstr** | transistor |
| **xtal** | crystal |
| **xtlo** | crystal oscillator |
| **Ω** | ohm(s) |
| **μ** | micro ($10^{-6}$) |

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisburg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884
Use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg. Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc. Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571
Use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
The Ross Milton Co.
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Div.
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, Massachusetts

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933
Use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

## Federal Supply Codes for Manufacturers (cont)

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988
Use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, Minnesota

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp.
Rectifier Division
Hicksville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Div.
AMF Canada LTD.
Guelph, Ontario, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
The Budd Co. Polychem Products
Plastic Products Div.
Bridgeport, Pennsylvania

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606
Use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors,
formerly Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics
Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
GTE Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

## Federal Supply Codes for Manufacturers (cont)

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Bucheye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co.
Corporate HQ
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
AB Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California

32879
Advanced Mechanical
Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
P.R. Mallory & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp. formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, California

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey

70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnback Radio Co., Inc.
Freeport, New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village
Chicago, Illinois

72005
Wilber B. Driver Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303

72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

## Federal Supply Codes for Manufacturers (cont)

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Bechman Instrument Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, California

73445
Amperex Electronic Corp.
Hicksville, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp.
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp.
Mepco Div.
A North American Phillips Co.
Norristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183
Use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Arnold Stevens, Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81483
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
The Carr Co., United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Div.
Eatontown, New Jersey

83330
Herman H. Smith, Inc.
Brooklyn, New York

83478
Rubbercraft Corp.
of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
John Fluke Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

## Federal Supply Codes for Manufacturers (cont)

90201
Mallory Capacitor Co.
Div. of P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211
Use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737
Use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div. of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154
Use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts, Div. of
Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic
Hardware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect.
Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779
Use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

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(404) 396-3224 (Atlanta)

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2125 S. 48th Street
Suite 104
Tempe, AZ 85282
(602) 967-8724
(602) 790-9881 (Tucson)

**CA, Los Angeles**
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20902 South Bonita St.
Carson, CA 90746
(213) 538-3900 or
(714) 761-2449

**CA, Santa Clara**
John Fluke Mfg. Co., Inc.
[illegible]00 Walsh Ave., Bldg. K
Santa Clara, CA 95050
(408) 727-0513

**CA, Tustin**
John Fluke Mfg. Co., Inc.
15445 Red Hill Ave., Suite F
Tustin, CA 92680
(714) 838-8863
(714) 226-1254 (San Diego)

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John Fluke Mfg. Co., Inc.
1980 South Quebec St. #4
Denver, CO 80231
(303) 750-1222

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John Fluke Mfg. Co., Inc.
124 Hebron Ave.
Glastonbury, CT 06033
(203) 633-0777

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John Fluke Mfg. Co.,Inc.
940 N. Fern Creek Ave.
Orlando, FL 32803
(305) 896-4881

**HI, Honolulu**
EMC Corporation
2979 Ualena St.
Honolulu, HI 96819
(808) 836-1138

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John Fluke Mfg. Co., Inc.
1027 Hollywood Blvd., #309
Iowa City, IA 52240
(319) 354-2811

**IL, Chicago**
John Fluke Mfg. Co., Inc.
1400 Hicks Road
Rolling Meadows, IL 60008
(312) 398-0850

**IN, Indianapolis**
John Fluke Mfg. Co., Inc.
5610 Crawfordsville Rd.
Suite 802
Indianapolis, IN 46224
(317) 244-2456

**KA, Kansas City**
John Fluke Mfg. Co., Inc.
4550 West 109th St.
Suite 130
Shawnee Mission, KA 66211
(913) 381-9800

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John Fluke Mfg. Co., Inc.
25 "B" Street
Burlington MASS
(617) 273-4674

**MD, Rockville**
John Fluke Mfg. Co., Inc.
5640 Fishers Lane
Rockville, MD 20852
(301) 770-1570
(301) 792-7060 (Baltimore)

**MI, Detroit**
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13955 Farmington Rd.
Livonia, MI 48154
(313) 522-9140

**MN, Minneapolis**
John Fluke Mfg. Co., Inc.
7373 West 147th Street
Suite 196
Apple Valley, MN 55124
(612) 432-9400

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John Fluke Mfg. Co., Inc.
300 Brookes Dr., Suite 100
Hazelwood, MO 63042
(314) 731-3388

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Greensboro, NC 27408
(919) 273-1918

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John Fluke Mfg. Co., Inc.
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Paramus, NJ 07652
(201) 262-9550

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Albuquerque, NM 87110
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Rochester, NY 14622
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Middleburg Heights, OH 44130
(216) 234-4540

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4756 Fishburg Rd.
Dayton, OH 45424
(513) 233-2238

**OR, Portland**
John Fluke Mfg. Co., Inc.
18360 S.W. Springfield Lane
Aloha, OR 97007
(503) 642-1342

**PA, Philadelphia**
John Fluke Mfg. Co., Inc.
1010 West 8th Ave., Suite H
King of Prussia, PA 19406
(215) 265-4040
(412) 261-5171 (Pittsburgh)

**TX, Austin**
John Fluke Mfg. Co., Inc.
111 W. Anderson Lane
Suite 213
Austin, TX 78752
(512) 478-9901
(512) 340-2621 (San Antonio)

**TX, Dallas**
John Fluke Mfg. Co., Inc.
14400 Midway Road
Dallas, TX 75234
(214) 233-9990

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John Fluke Mfg. Co., Inc.
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Houston, TX 77055
(713) 683-7913

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782 East 8325 Street
Sandy, UT 84070
(801) 566-4864

**WA, Seattle**
John Fluke Mfg. Co., Inc.
975 Industry Drive
Seattle, WA 98188
(206) 575-3765

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Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands. Phone (013) 673973
Litho in U.S.A. 3/81

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Australia 2137
Tel: (2) 736-2888, TLX: 79025887

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Mt. Waverly, VIC. 3149
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Tel: 233-4044
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Professional Suite's Bldg.
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Brisbane, 4001, Australia
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G.P.O. Adelaide 5001
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Elmeasco Instruments Pty. Ltd.
P.O.Box 95, Gosnells
West Australia 6110
Tel: (09) 348-3362

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Walter Rekirsch
Elektronische Gerate GmbH & Co.
Vertriebs-KG., Obachgasse 28
A-1220 Vienna, Austria
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Casilla 7295, La Paz, Bolivia
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01234 Sao Paulo S.P., Brazil
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30.000 Belo Horizonte M.G., Brazil

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Arotec S.A.
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02000 Rio de Janeiro, R.J., Brazil
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Calgary, Alberta T2E 6Z5
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3795 William Street
Burnaby, British Columbia V5C 3H3
Tel: (604) 294-1326

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192 Joseph Zatzman Dr.
Suite 4
Burnside Industrial Park
Dartmouth, Nova Scotia B3B 1N4
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881 Lady Ellen Place
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Mississauga, Ontario L4V 1J5
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Allan Crawford Assoc., Ltd.
7018 cote de Liesse
St. Laurent, Quebec H4T 1E7
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Manuel Montt 024 - Of. D
Casilla 16228, Santiago 9, Chile
Tel: 44940
TLX: No 40301 Cab. Publ.,
Attn: Intronica Chile

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TLX: 152662 JOHNFLUKE MTLT

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Coasin Ltda.
Carrera 13, No. 37-37, Of. 401
Ap. Aero 29583
Bogota DE, Colombia
Tel: 232-45-32, TLX: 45787

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Tel: (2) 658111, TLX: 35293

**Ecuador** ●
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Edificio "Jerico"
Ave. 12 de Octubre #2285 y
Ave. Orellana (Planta Baja)
Quito, Ecuador
Tel: 529684, TLX: 2865 Protec Ed

Proteco Coasin Cia., Ltda.
Calderon 103Y Malecon
Casilla #9733
Guayaquil, Ecuador
Tel: 526093

**Egypt and Sudan** ■
Lotus Engineering Organisation
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22, Kaft El Nil
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32 Brews Hill
Naven, County Meath, Ireland
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Puh: (0) 5052255
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TLX: 0184978

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Hellenic Scientific Representations Ltd.
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## Section 8

# Schematic Diagrams


| FIGURE NO. | NAME | DRAWING NO. | PAGE |
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| 8-1. | A1A1 Thermometer PCB Assembly Component Location . . . | 2165A-1601 | 8-2 |
| 8-2. | A1A1 Thermometer PCB Assembly Schematic . . . . . | 2165A-1001 | 8-3 |
| 8-3. | A2 Display PCB Assembly Component Location . . . . . | 2165A-1603 | 8-4 |
| 8-4. | A2 Display PCB Assembly Schematic . . . . . | 2165A-1003 | 8-5 |
| 8-5. | A3 Type Select PCB Assembly Component Location . . . . . | 2160A-1612 | 8-6 |
| 8-6. | A3 Type Select PCB Assembly Schematic . . . . . | 2160A-1012 | 8-6 |

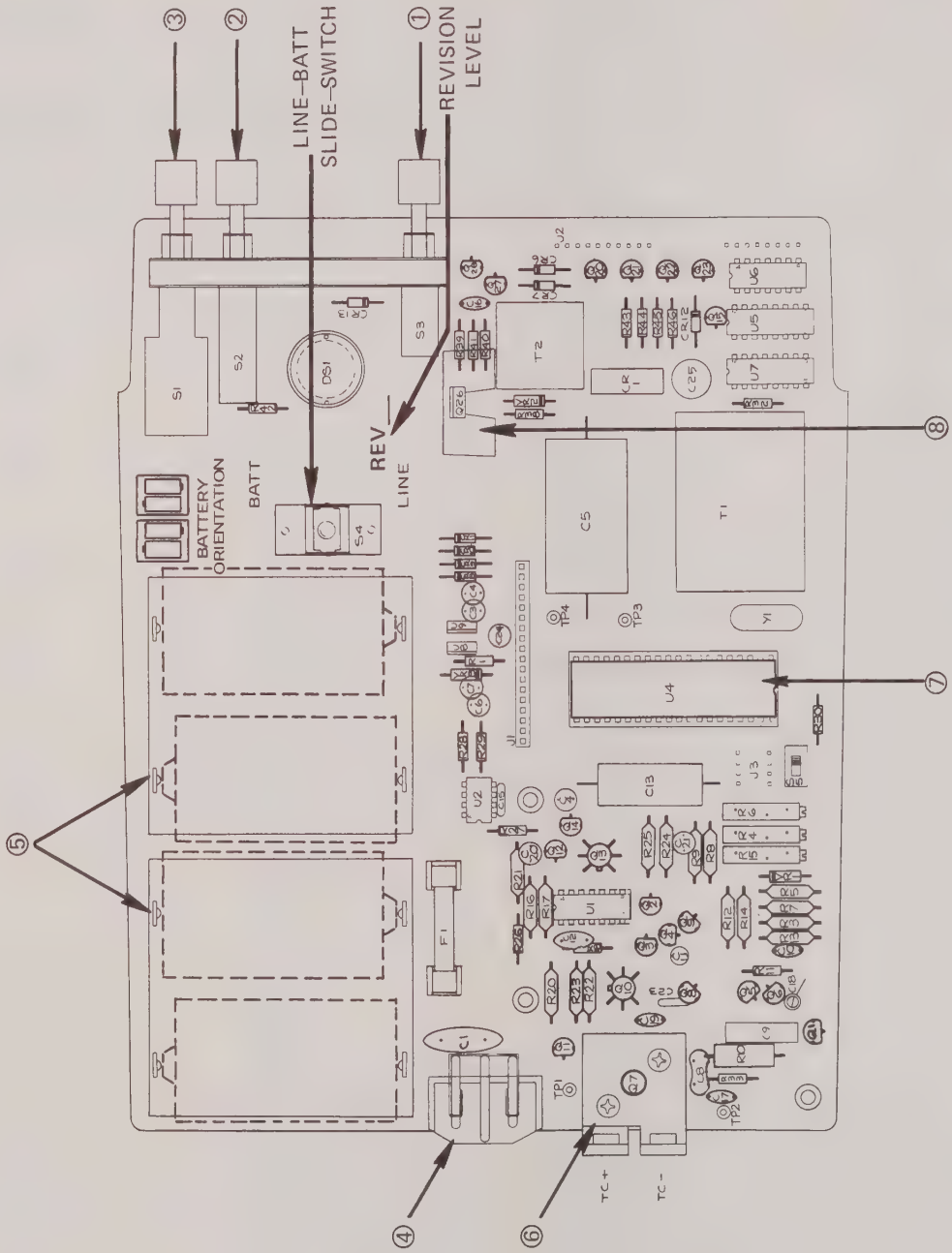



Figure 8-1. A1A1 THERMOMETER PCB ASSEMBLY COMPONENT LOCATION (2165A-1601)

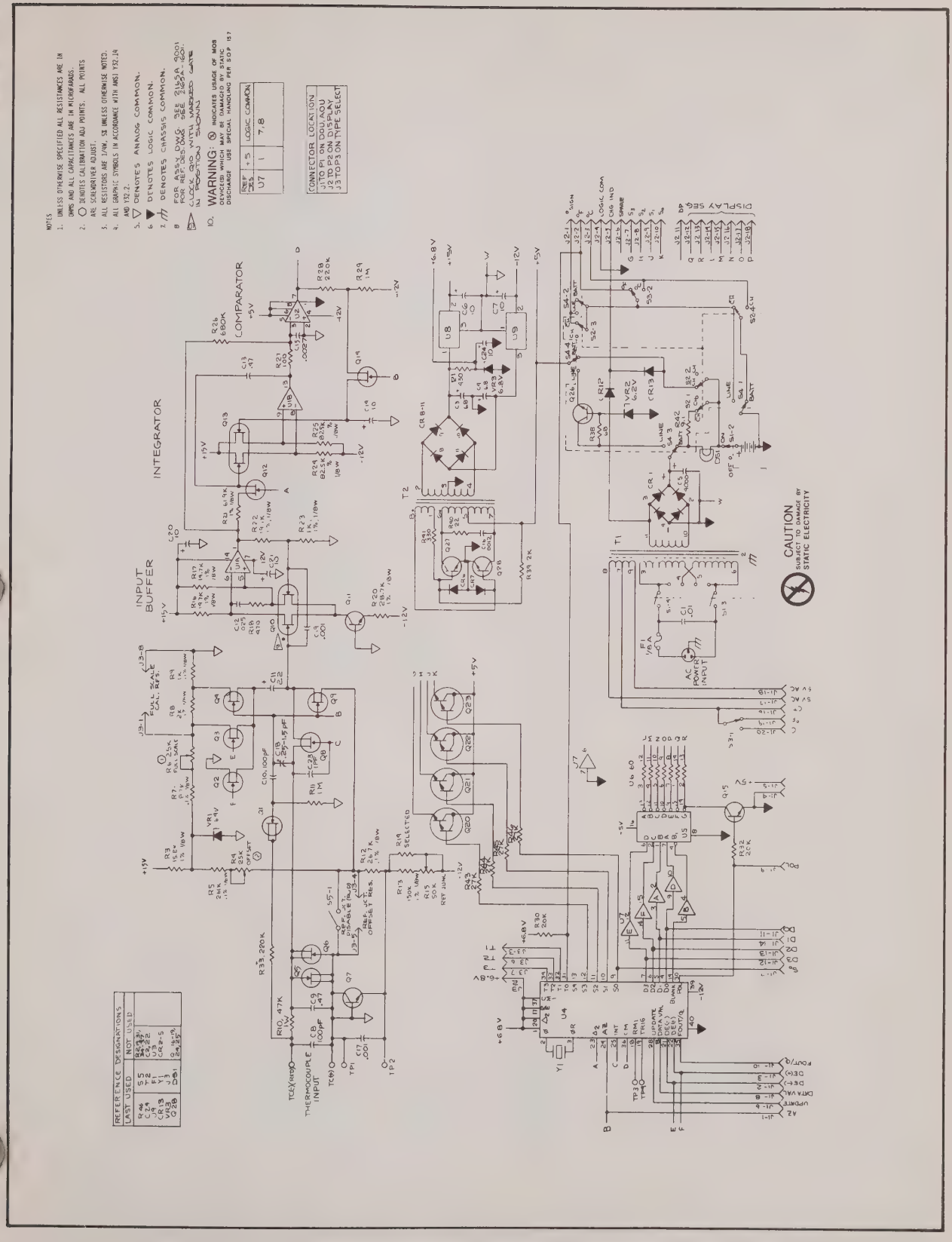

NOTES
1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ○ DENOTES CALIBRATION ADJ POINTS. ALL POINTS ARE SCREWDRIVER ADJUST.
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE NOTED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.14 AND Y32.2.
5. ▽ DENOTES ANALOG COMMON.
6. ▼ DENOTES LOGIC COMMON.
7. ⏚ DENOTES CHASSIS COMMON.
8. FOR ASSY DWG: SEE 2165A-2001 FOR REF DES NOT SHOWN SEE 2165A-2001.
9. ⚠ LOGIC DEVICES WITH HARDED GATE IN 1 POSITION SHOWN.
10. WARNING: ⊗ INDICATES USAGE OF MOS DEVICES WHICH MAY BE DAMAGED BY ESD DISCHARGE USE SPECIAL HANDLING PER SOP 157
REF DES | +5 | LOGIC COMMON
U7 | 1 | 7,8
CONNECTOR LOCATION
J1 TO P1 ON DOU/AOU
J2 TO P2 ON DISPLAY
J3 TO P3 ON TYPE SELECT
REFERENCE DESIGNATIONS
LAST USED | NOT USED
R24 | S5 | S4,S7
U7 | F2 | U1
U3 | F1 | U2
VR3 | J3 | CR2-5
Q28 | D81 | Q1,Q29
INPUT BUFFER
INTEGRATOR
COMPARATOR
THERMOCOUPLE INPUT
FULL SCALE
OFFSET
REF JUNC. OFFSET RES.
SELECTED
DISPLAY SEL
CAUTION
SUBJECT TO DAMAGE BY STATIC ELECTRICITY
AC POWER INPUT

Figure 8-2. A1A1 THERMOMETER PCB ASSEMBLY SCHEMATIC (2165A-1001)

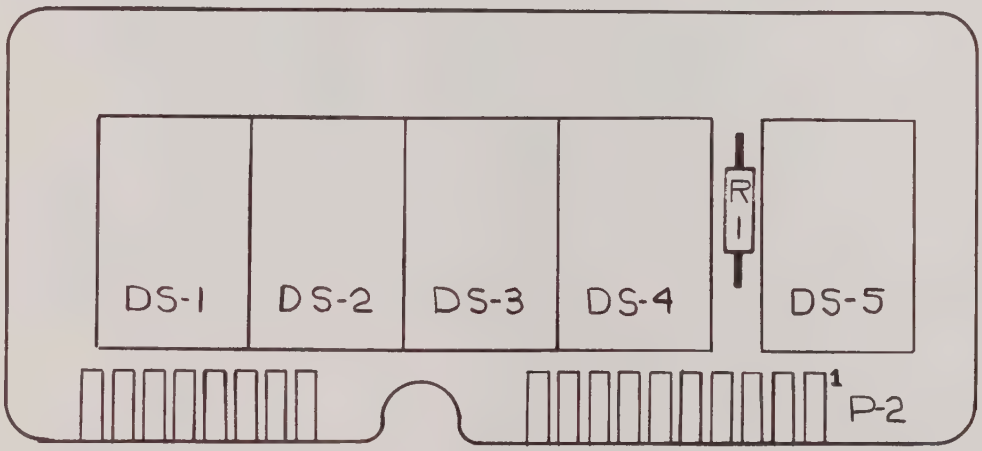
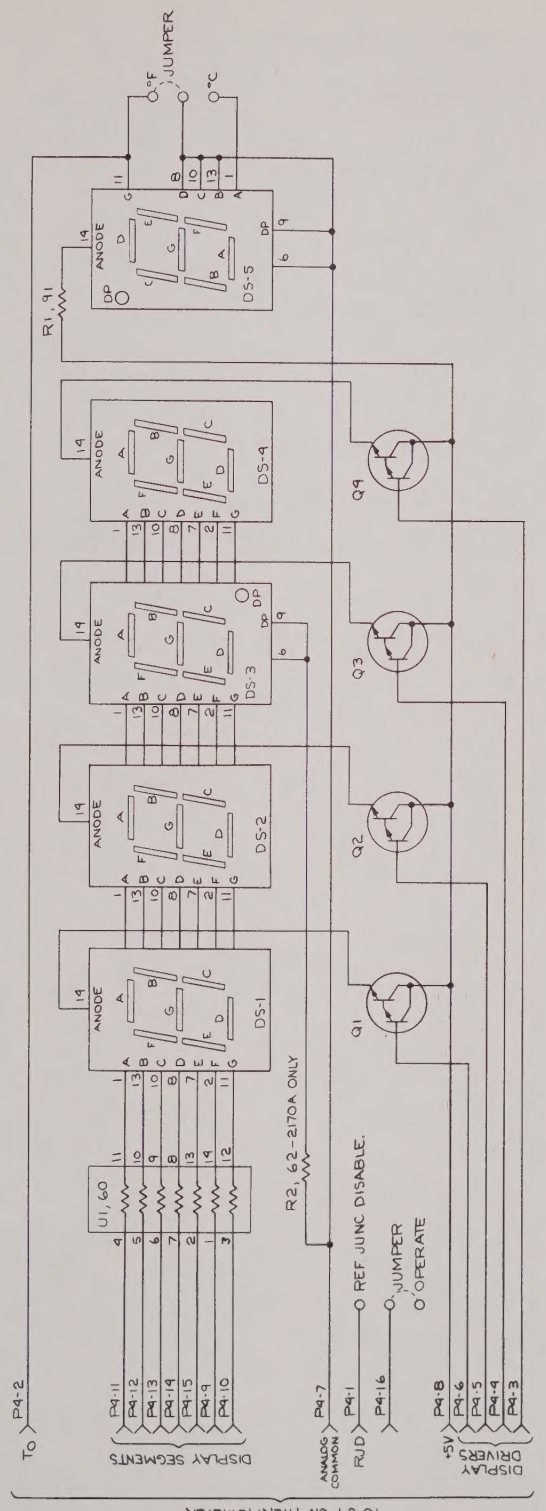



Figure 8-3. Figure 8-3. A2 DISPLAY PCB ASSEMBLY COMPONENT LOCATION (2165A-1603)




NOTES:
1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ○ DENOTES CALIBRATION ADJ POINTS. ALL POINTS ARE SCREWDRIVER ADJUST.
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE NOTED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.14 AND Y32.2.

**Figure 8-4. A2 DISPLAY PCB ASSEMBLY SCHEMATIC (2165A-1003)**

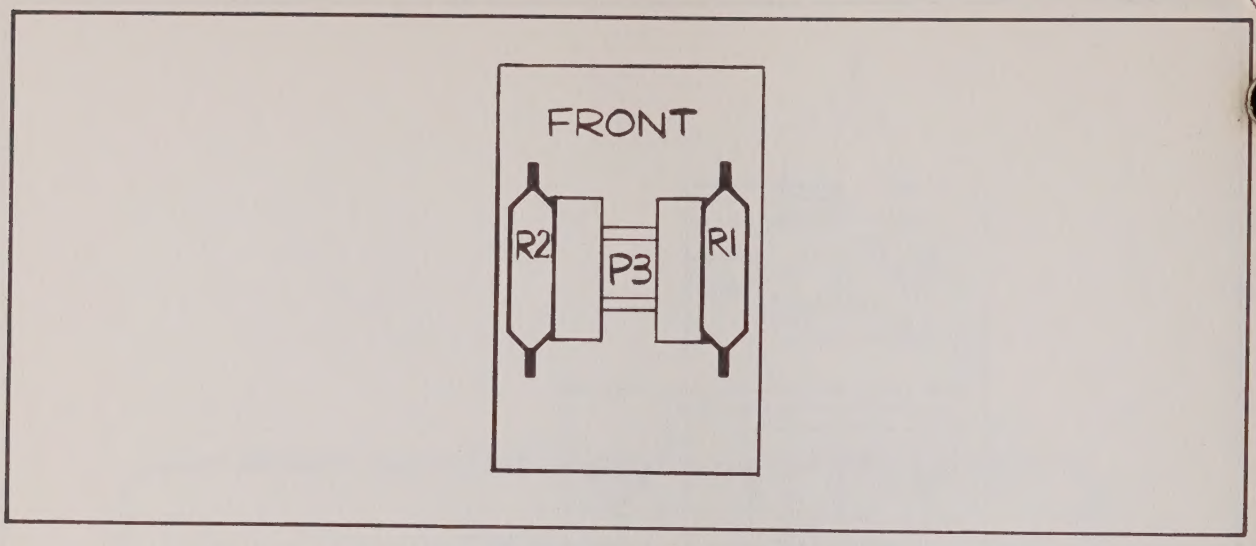
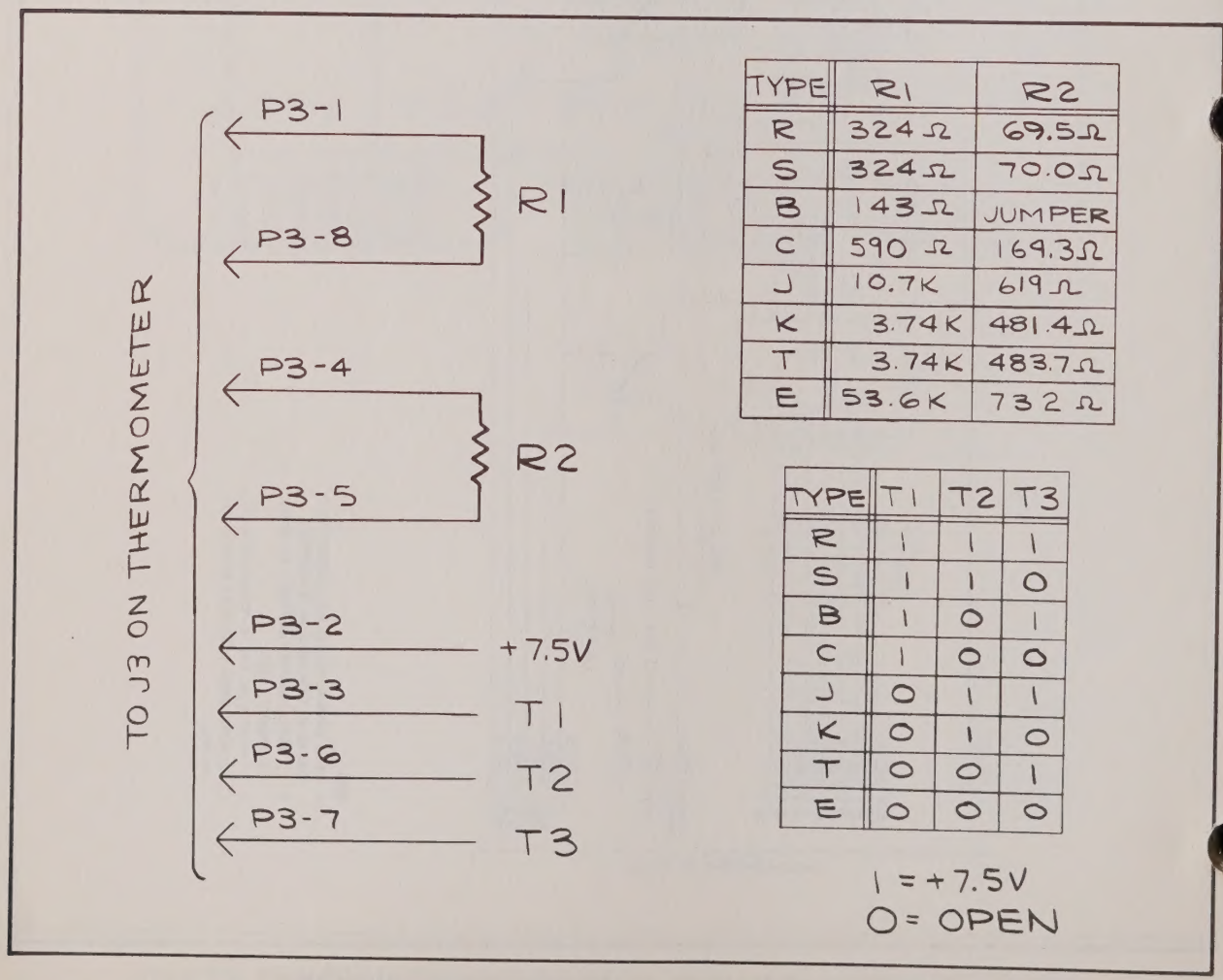



Figure 8-5. A3 TYPE SELECT PCB ASSEMBLY COMPONENT LOCATION (2160A-1612)




| TYPE | R1 | R2 |
|---|---|---|
| R | 324 Ω | 69.5Ω |
| S | 324 Ω | 70.0Ω |
| B | 143 Ω | JUMPER |
| C | 590 Ω | 169.3Ω |
| J | 10.7K | 619 Ω |
| K | 3.74K | 481.4Ω |
| T | 3.74K | 483.7Ω |
| E | 53.6K | 732 Ω |

| TYPE | T1 | T2 | T3 |
|---|---|---|---|
| R | 1 | 1 | 1 |
| S | 1 | 1 | 0 |
| B | 1 | 0 | 1 |
| C | 1 | 0 | 0 |
| J | 0 | 1 | 1 |
| K | 0 | 1 | 0 |
| T | 0 | 0 | 1 |
| E | 0 | 0 | 0 |

1 = +7.5V
0 = OPEN

Figure 8-6. A3 TYPE SELECT PCB ASSEMBLY SCHEMATIC (2160A-1012)

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